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CONCRETE
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CONSTRUCTIONAL ENGINEERING

VOL. IV. 1909. Nos. 1 to 7.

A MONTHLY JOURNAL FOR ENGINEERS, ARCHITECTS, SURVEYORS & CONTRACTORS and all interested in CEMENT, CONCRETE, REINFORCED CONCRETE, FIRE-RESISTING CONSTRUCTION and STRUCTURAL STEEL.

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TO
VOLUME IV.

(Nos. 1 to 7).

Published at Dewar House, Haymarket, London, S.W.

1909

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume IV. No. 1. LONDON, MARCH, 1909.

EDITORIAL NOTES.

WITH the current issue, CONCRETE AND CONSTRUCTIONAL ENGINEERING enters into its fourth year, and in looking through our volumes of 1906, 1907 and 1908, we are proud to observe the gradual steady increase in the uses of concrete, and reinforced concrete in particular, throughout the British Empire, to which increase we consider we have contributed by the publicity we have given to all matters of importance concerning the subject. In particular we hold that the manner in which we have been able to illustrate examples of work done both at home and abroad has materially assisted in creating confidence among those who were diffident as to employing the more modern methods of concrete construction. That it has been possible to materially assist in creating such confidence has been due to two reasons. In the first place, we have used every effort to be independent in the presentation of facts and views. In the second place, this effort to be independent having been recognised by the leaders of the technical professions concerned, this journal is read by men of influence, *i.e.*, by those who control the majority of the large building and civil engineering works of the Empire. We have, in short, successfully avoided the failings of the minor journal which so often loses its independence in the temptations offered by those who think a "puff" is valuable, no matter how small the standing of the reader to whom it is presented. We have thereby gained a large number of readers of the highest professional standing to whom the serious character and the independence of the matter presented, alone serve as an attraction to take up the journal for careful perusal. These influential readers, we are pleased to hear, not only find the literary contents and illustrations useful, but also find the pictorial announcements in our advertisement pages instructive and handy for reference.

We hope to continue our policy as heretofore.

THE INSTITUTION OF CIVIL ENGINEERS AND REINFORCED CONCRETE.

IT may be recollected that we presented early information in our previous issue that the Council of the Institution of Civil Engineers had at last been persuaded to consider the advisability of taking up the research work necessary for obtaining additional technical data as to reinforced concrete.

We expressed our hope that whatever the Institution might do, it might be in co-operation with other bodies interested in the subject. We indicated that as the Institution in Great George Street had missed the opportunity of

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doing pioneer work at a period when it was really most required, it might be advisable to avoid anything that would not lead to harmony and uniformity with what was being done elsewhere.

We now understand that the Council of the Institution of Civil Engineers has appointed a committee on reinforced concrete, and that certain of the public authorities are receiving requests to appoint representatives on that committee, but we cannot trace, as yet, that any of the institutions directly concerned have been approached. We hold that the Royal Institute of British Architects—who have done such able pioneer work—the Concrete Institute, and also the British Fire-Prevention Committee, should be requested to co-operate if the findings of this new committee are to have general recognition. We also feel that the Council would have been well advised, when forming the committee from among its own members, to select mainly men who have already had considerable experience in the design and supervision of reinforced concrete work. As it is, but few of the members elected have had this experience, for they comprise, as far as we are aware at the moment, it is true, engineers of great influence and high attainments, but, with two notable exceptions, rather the onlookers than the users of the material under inquiry.

As constituted at present, we believe the committee comprises:—Sir John Wolfe Barry, K.C.B.; Mr. B. Hall Blyth, M.A.; Dr. George F. Deacon; Mr. Maurice Fitzmaurice, C.M.G.; Mr. W. R. Galbraith; Mr. A. G. Lyster; Sir William Matthews, K.C.M.G.; Sir W. C. Unwin, F.R.S.; and the President of the Institution of Civil Engineers (Mr. J. C. Inglis).

With the exception of Professor Unwin, it should perhaps also be remarked that none of these members assisted on the Reinforced Concrete Committee of the Royal Institute of British Architects, and curiously not one of the number happens to be a member of the Concrete Institute, although there are over two hundred members of the Great George Street Institution who are members of that body.

We think the Council of the Institution of Civil Engineers will be well advised to take a somewhat broader view of the question in constituting its committee on reinforced concrete.

MARKING OF PACKAGES OF PORTLAND CEMENT.

We referred in our previous issue to the importation of natural or adulterated "Portland" cement from abroad, and we would like to take this opportunity of pointing out that if the Board of Trade eventually decides to obtain legislative powers or finds some other means to enforce shippers of foreign hops to specially mark their packages in such a manner as to indicate that they are of foreign origin, a similar procedure could be most advisably adopted in respect to the packages imported from abroad which contain "Portland" cement or its substitutes.

The natural and adulterated "Portland" cements coming from abroad, and from Belgium in particular, are not reliable. They are dangerous to a high degree, and no architect or engineer of professional standing would dare to

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knowingly risk their use, whilst contractors, as a rule, also fight shy of these foreign products.

Unfortunately, however, quite a quantity—*i.e.*, one hundred thousand tons—of this imported material were used in Great Britain during the last twelve months, mostly, we believe, entirely without the users knowing what had been delivered to them. The foreign material is all too often purchased from agents or builders'-merchants under false labels, and the fraud goes on undiscovered.

That nothing can be done to penalise such sales as is done on the sale of false drugs or dangerous foods seems most regrettable, and it would certainly be a step in the right direction if the Board of Trade could take a broader view than it does of its duties under the existing enactments and prevent some of the dangers accruing therefrom.

Pending legislative action as above indicated, it should be pointed out that there is a requirement in the British Standard Specification for Portland Cement which is not sufficiently insisted upon by consumers, and which was largely designed to prevent fraudulent trading of the character above described. Clause 2 of the specification distinctly states that "the cement shall be delivered in packages marked with the manufacturer's name." It therefore follows that when Portland cement is purchased in the open market for delivery in accordance with the standard specification, the consumer is entitled, as a matter of course, to receive it in packages which will give him this very necessary if not essential information.

It is significant that the report of the Joint Committee on Reinforced Concrete, adopted by the Royal Institute of British Architects in 1908, also contained this requirement as to the branding of packages, and it is also interesting to note that the new German standard specification includes this very necessary stipulation.

It may be accepted as a fact that if cement is received with the name of an English manufacturer of repute branded clearly upon the packages that the material is not only of British manufacture, but is fully up to the requirements of the standard specification.

THE CONCRETE INSTITUTE.

THE Concrete Institute appears to have been making further considerable progress, for at its meeting on February 18th it was announced that the membership had already exceeded five hundred.

This is certainly a most interesting indication of the increased interest in the subject of concrete and reinforced concrete, and it is also pleasant to observe that so large a proportion of the membership comprises members and associate-members of the Institution of Civil Engineers, Royal Engineer officers, and architects and surveyors holding public appointments.

At its last meeting the Institute devoted itself to some of the commercial aspects of reinforced concrete, which certainly require most careful consideration at the moment. We think the Institute did well to devote an evening to the discussion of these matters, for they have been all too much neglected, and the proposal which was made in the course of the discussion, that some standard

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form of "specialist" contract should be devised by the Concrete Institute, should, we think, be dealt with promptly.

BRITISH PATENT RIGHTS AND REINFORCED CONCRETE PILES.

THE action, which was started under the name of "Mouchel and another v. Coignet and others," came on in the first instance before Mr. Justice Warrington in June and July, 1906, and was reported in CONCRETE of September, 1906. The original plaintiffs were Messrs. Mouchel and Hennebique, and the defendants were Messrs. E. Coignet, William Cowlin & Sons, and G. C. Workman. The patent in question was Hennebique's patent No. 10,203, of 1897, and it was alleged the defendants had infringed it.

The patent related to piles formed of bars of iron embedded in concrete, and cross-tied by cramps, and also to a metal cap for use with such piles when ramming. Various anticipations were alleged, among others Brannon's British Specification No. 2,703, of 1871, and Stempel's U.S.A. Specification No. 411,360.

Mr. Justice Warrington held that the patent was valid, and that Messrs. Cowlin & Son had infringed Claim 1 by the use of certain piles at Bristol. But as regards Mr. E. Coignet and Mr. G. C. Workman he dismissed the action with costs.

From this decision Cowlin & Son appealed, and the Court of Appeal, consisting of the Lord Chief Justice and Lords Justices Farwell and Buckley, held that the patent was invalid, having been anticipated by Brannon and others. The appeal was reported in CONCRETE of May, 1907.

The tables having been turned in this way, Mr. Hennebique appealed, and the case was heard in the House of Lords last month—*i.e.*, on February 23rd—Mr. L. G. Mouchel having (as reported in these columns) died in the interval.

The case in the House of Lords only occupied a day, and judgment was given in favour of the respondents—that is, Messrs. Cowlin & Son. The Lords of Appeal held that the judgment of the Court of Appeal was right—that the Hennebique patent had been anticipated, and was therefore invalid, that thus no infringement had taken place, and the appeal was dismissed with costs.

Mr. Coignet, who is represented in Great Britain by Messrs. E. Coignet, Ltd. (of which company Mr. Workman is a director), is thus free to continue the construction of piles as originally intended either directly or through licensees.

The litigation which was commenced some three years back in respect to the Coignet piles is thus at last terminated, and an important question of principle has been decided which will materially accelerate the introduction of reinforced concrete piles in the British Empire.

The expense of deciding this point must have been great, probably not much below £8,000, of which perhaps three-fourths have fallen on the shoulders of Mr. Hennebique and his London office, and one-fourth on Mr. Coignet and his friends.

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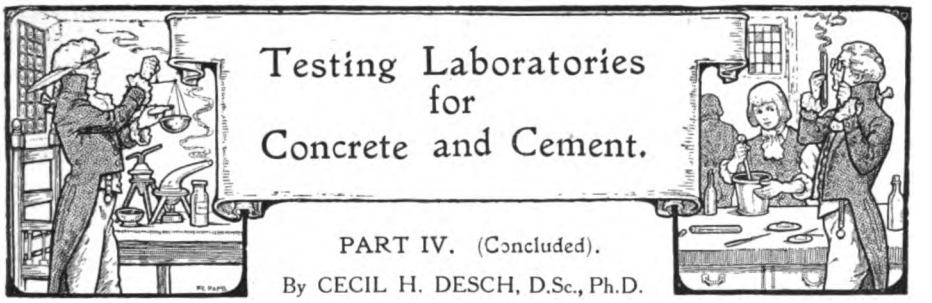

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This laboratory is under the control of the United States Geological Survey, with which an Advisory Board co-operates, the latter body consisting of representatives of those Government departments which are concerned with engineering and building work, and of the chief American engineering societies and institutions. A joint committee on concrete and reinforced concrete, appointed separately in 1904, now also works in harmony with the Advisory Board. The amount voted by Congress towards the work during the last year (July, 1907, to June, 1908) was about £20,000, but the laboratory also receives advantages in the shape of free materials and transport from many railways and commercial organisations.

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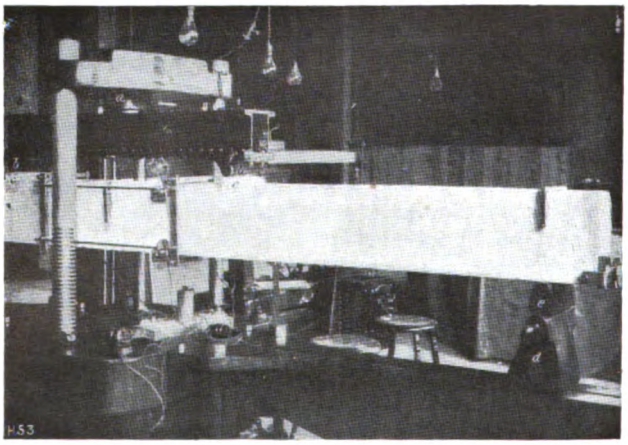

FIG. 2. STRUCTURAL MATERIALS TESTING LABORATORY, ST. LOUIS, U.S.A. Reinforced Concrete Beam in Testing Machine ready for application of Load.

The extensive use of concrete building-blocks in the United States has made it necessary to make special provision for tests of this kind, a test of transverse strength being first made, the broken halves then being utilised for two tests in compression.

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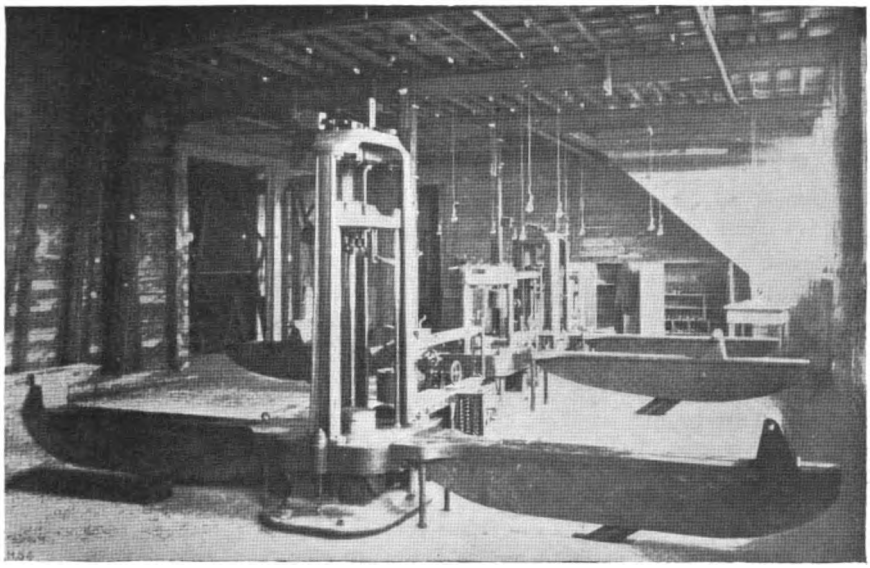

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Interior view of Testing Room, Beam Section.

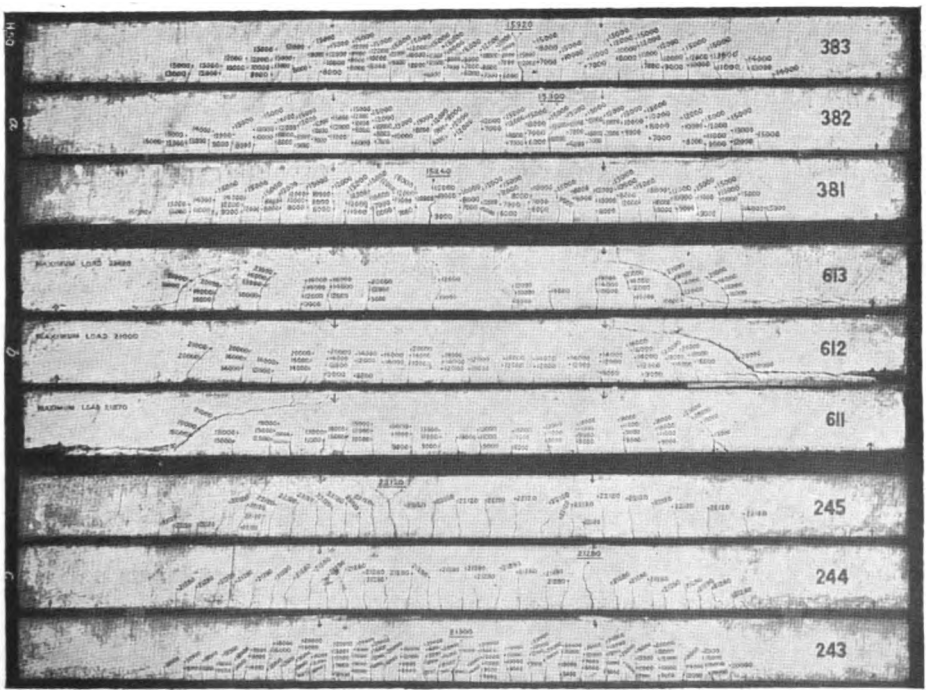

FIG. 3. STRUCTURAL MATERIALS TESTING LABORATORY, ST. LOUIS, U S A.
Method of recording character of Reinforced Concrete Beam Failures.

a. & c. Typical failures by reaching elastic limit.
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The Underwriters' Laboratory, Chicago.

Fire tests are made on concrete blocks, portions of concrete beams, patent partitions, etc., the fire-testing chamber of the Underwriters' Laboratory in Chicago being used for this purpose. The chamber used is heated by gas, the temperature being raised to 925° C. in about 30 minutes, and maintained at that for one and a half hours longer. After testing, some of the blocks have been tested under transverse and compressive stress. *Fig.* 4 shows the general arrangement of the fire chamber with pyrometers, etc. The frame to the right allows a partition to be run out while hot, for the purpose of spraying water on it.

The only other apparatus for notice is that for making permeability tests, which takes 12 blocks for simultaneous testing.

A chemical laboratory is provided for the complete analysis of the cement, sand, and steel used in the experiments.

Summary.

It will be seen from this series of articles that great variety is to be found in the equipment of the various laboratories in which investigations into the properties of concrete and reinforced concrete are conducted. But whilst it is only possible to carry out investigations of a very comprehensive character in great State-aided institutions of the type of that at Gross-Lichterfelde, it is nevertheless true that much valuable work is done in laboratories possessing a much more modest equipment. A proper co-ordination of the different establishments in which testing can be carried on, avoiding unnecessary duplication and ensuring uniformity of method, is very desirable. Great as is the amount of work performed in connection with reinforced concrete in recent years, much remains to be done in order to clear up points which now remain obscure, to the great disadvantage of those engaged either in designing or in constructing works of this kind.

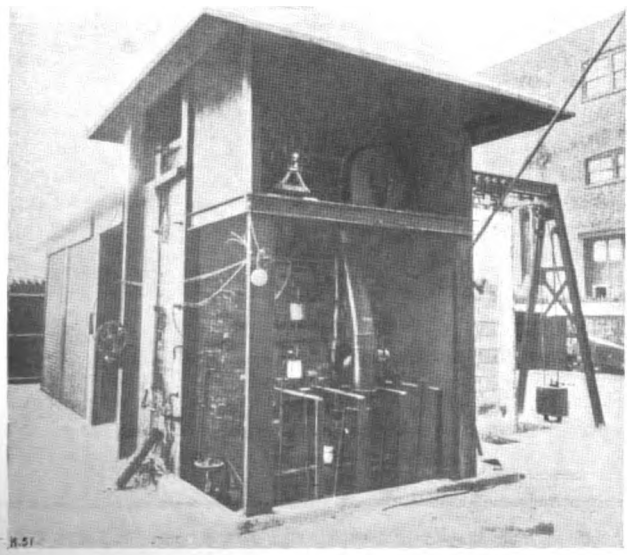

FIG. 4. UNDERWRITERS' LABORATORY, CHICAGO.
Heating Chamber, showing regulating apparatus for gas and air.

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STEEL AND CONCRETE AT THE SELFRIDGE STORES, LONDON

By
S. BYLANDER.

We are in this issue presenting some of the principal constructional drawings of the building known as the Selfridge Stores, which embodies the very latest ideas of a composite structure, comprising steel framing and reinforced concrete. The building is, in fact, a steel frame building in which all the steel work is embedded in concrete, the floors being reinforced concrete floors reinforced with a steel bar.

The building is one of the first, if not the first, in the Metropolis to which the recent amendments to the London Building Act have been applied, and which thus comprises a number of compartments of 450,000 cubic feet each, separated from one another by divisional walls, in which the door openings are also of larger area than was allowable before the passing of the new Act—i.e., 12 ft. by 12 ft.

In this particular case everything appears to have been done that ingenuity could devise to make this building of large cubical extent as safe as possible from the fire point of view, for not only has all the steel framing been well embedded in a suitable concrete, and the reinforcing bars in the reinforced concrete floors duly protected by concrete, but the door openings in the divisional walls have been equipped with modern automatic roller steel shutters, and excellent hydrant and sprinkler systems installed throughout the structure.

In the protection of the steel framing, in the selection of the reinforced concrete floors, and in the specification of the roller shutter doors, the latest experience obtained from the British Fire Prevention Committee's Reports has been applied. For the concrete protecting the steel framing aggregate of small size and Portland Cement of fine grinding have been used, whilst the type of floor applied and the type of roller shutter installed had both passed official fire-tests of four hours' duration, and had obtained the classification of "Full Protection" (Class "B.")

The building does great credit to the designers, Messrs. Burnham & Co., of Chicago, and Mr. Frank Atkinson, F.R.I.B.A., of London, as also to the various other architect and civil engineer specialists who have been called in to advise from time to time. It does equal credit to the contractors, Messrs. Waring and White (1906) Ltd., the engineering department of which firm prepared all the drawings for the steel frame work and floors.

Last, but not least, it does great credit to Mr. Selfridge, who by his perseverance did much, not only to obtain a building of very high qualities, but also to improve the legislative conditions under which it was executed.—ED.

THE new building, known as Selfridge Stores, which has been erected in Oxford Street, London, W., is on a site measuring 250 ft. by 175 ft., and the building occupies the whole site, no central areas or courts being constructed.

The frontages are to Oxford Street, Duke Street, and Somerset Street, of which the former is the most important.

Some small buildings on the other side of Somerset Street are connected to the main building by means of tunnels. These buildings are used generally for packing and despatching goods, and are not referred to as part of the Selfridge Stores in this article.

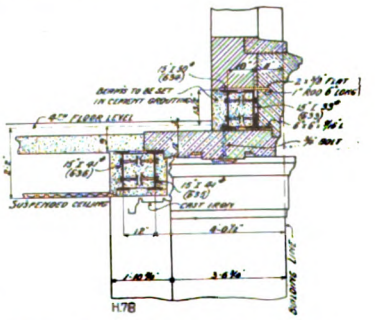

FIG 1. SPANDRIL SECTION AT 4TH FLOOR.

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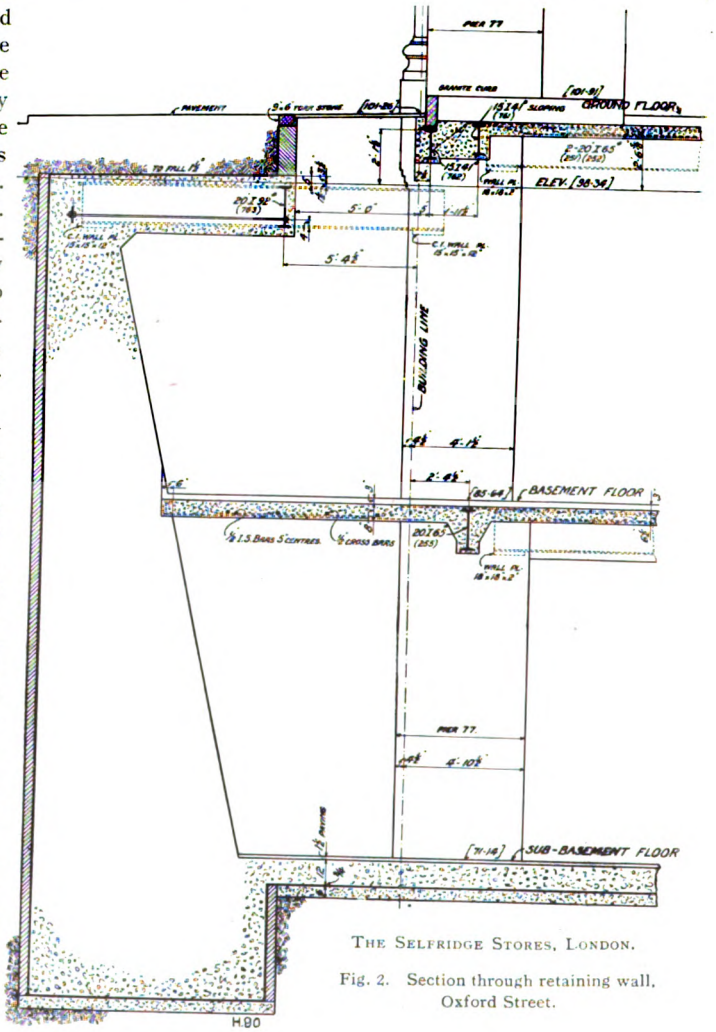
It was originally intended to connect the new building with Bond Street Tube Station on the Central London Railway and run the passenger lifts in the new building down to the same level as the lifts of the tube railway, but permission to carry out this scheme could not be obtained.

The building has three basements and five storeys above ground, the average height of each storey being 15 ft. The total area of floors is 277,500 ft. super. The flat roof is 80 ft. above, and the foundations 60 ft. below street level. The top of the parapet balustrading is 150 ft. above the foundations.

Underpinning.—The work in connection with the foundations was commenced at the earliest possible date, in view of the great depth of the excavations and the underpinning of adjoining walls, and in order to have everything clear and ready for the speedy erection when the delivery of the steelwork commenced. The underpinning of the adjoining building at the west party walls was the first work to be undertaken. The party wall of the store was built from the basement to the first floor level, and bonded into the old adjoining walls for the purpose of strengthening this wall, which was very old and unreliable. The old wall was not counted as part of the thickness of the wall for the store. The combined walls were strutted and underpinned in lengths of about 6 ft. to a depth of about 60 ft. below the street level.



THE SELFRIDGE STORES, LONDON.

Fig. 2. Section through retaining wall, Oxford Street.

One of the old buildings at the corner of Oxford Street and Duke Street was not allowed to be pulled down at the time when the foundations had to be put in for this portion of the new building, so a scheme was prepared for carrying the old building

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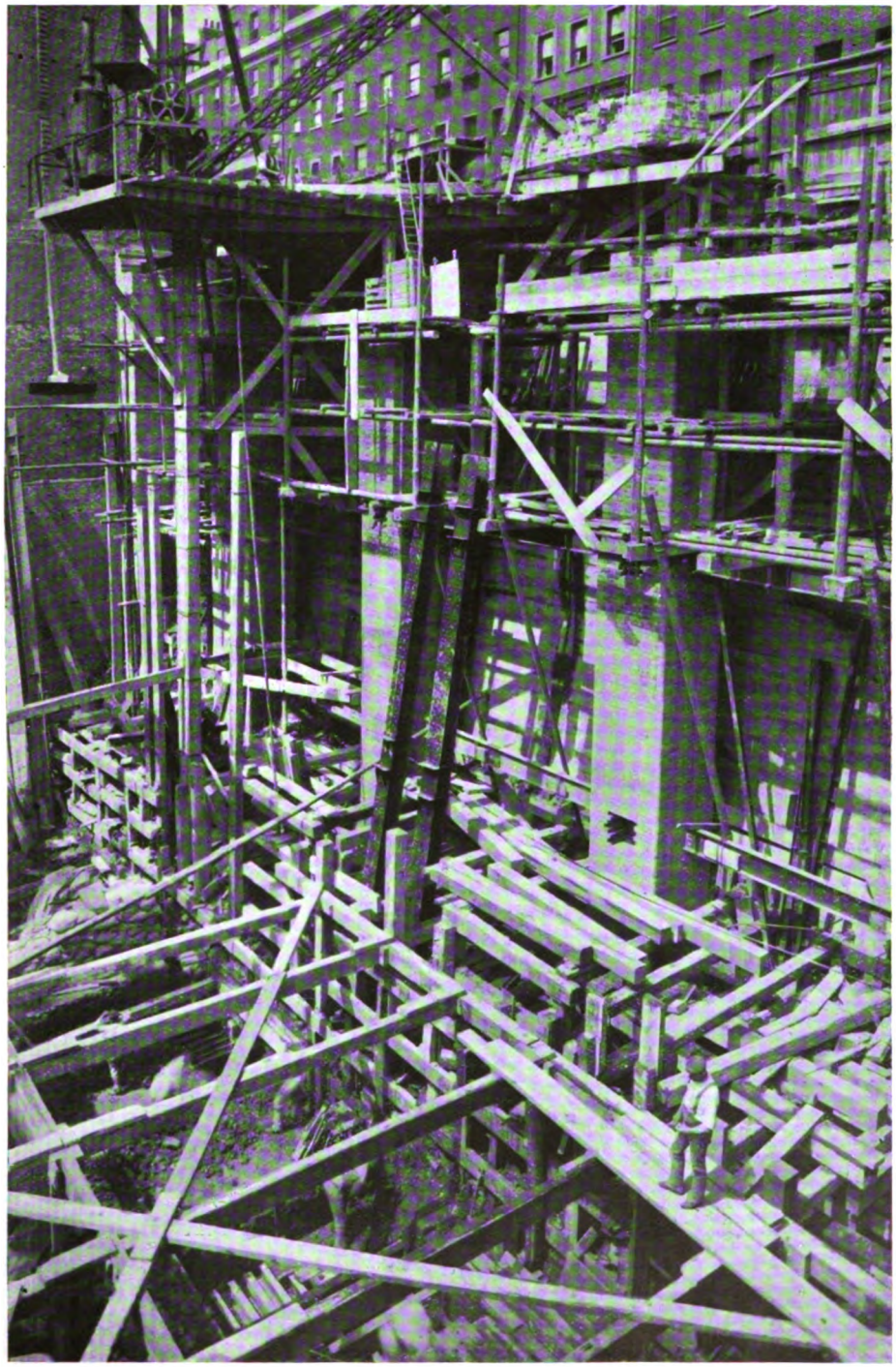

THE SELFRIDGE STORES, LONDON.

Fig. 3. Elevation of reinforced concrete retaining wall to Somerset Street, showing portion of the strutting still left in.

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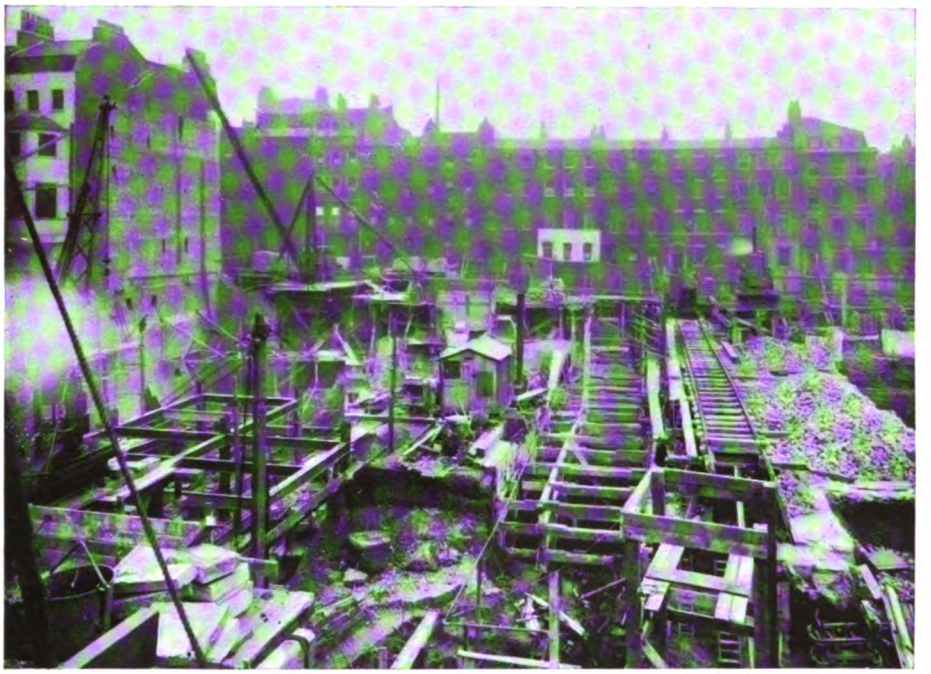

THE SELFRIDGE STORES, LONDON.

Fig. 4. View towards Somerset Street showing excavation in west block partly done, and the steel in sub-basement in place. Track for travelling crane used for excavating and putting in the retaining wall between the west and centre blocks.

THE SELFRIDGE STORES, LONDON.

Fig. 5. Corner of Duke and Oxford Streets, showing the old building still intact up to the third floor.

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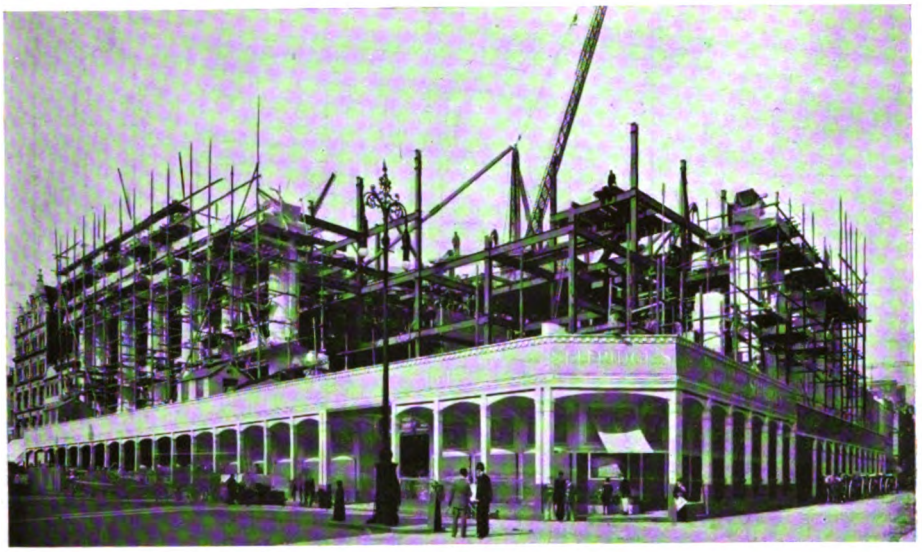
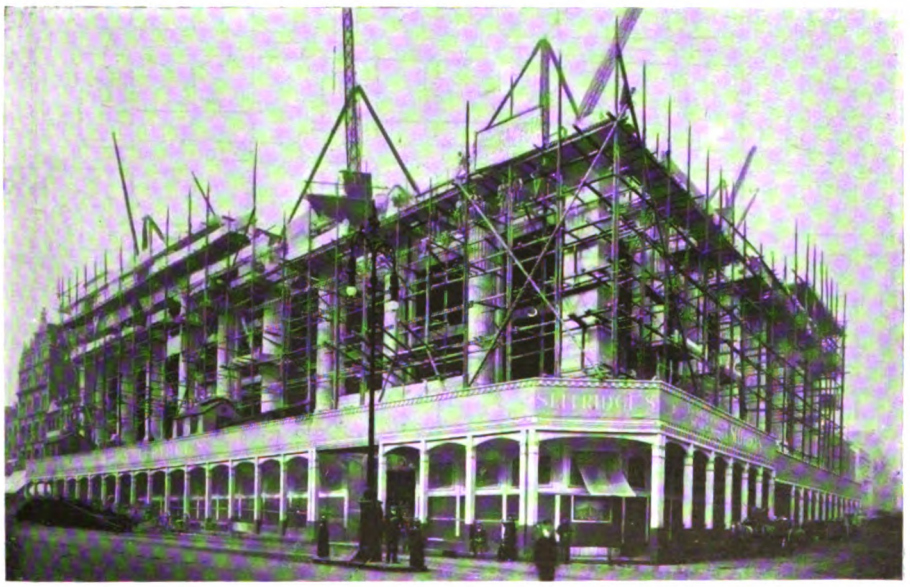
(which was four storeys above ground) on steel needle beams while the excavations for the new basement were made, and large foundations put in below the existing building.



THE SELFRIDGE STORES, LONDON.
Fig 6. Steelwork erected to the third floor, except last bay. No walls yet erected above ground floor.



THE SELFRIDGE STORES, LONDON.
Fig. 7. Steelwork and stonework erected complete up to the fourth floor level.

This scheme, however, was not carried into execution, as permission was granted to pull down the old building before the work was begun. The rapid progress of construc-

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form of "specialist" contract should be devised by the Concrete Institute, should, we think, be dealt with promptly.

BRITISH PATENT RIGHTS AND REINFORCED CONCRETE PILES.

THE action, which was started under the name of "Mouchel and another v. Coignet and others," came on in the first instance before Mr. Justice Warrington in June and July, 1906, and was reported in CONCRETE of September, 1906. The original plaintiffs were Messrs. Mouchel and Hennebique, and the defendants were Messrs. E. Coignet, William Cowlin & Sons, and G. C. Workman. The patent in question was Hennebique's patent No. 10,203, of 1897, and it was alleged the defendants had infringed it.

The patent related to piles formed of bars of iron embedded in concrete, and cross-tied by cramps, and also to a metal cap for use with such piles when ramming. Various anticipations were alleged, among others Brannon's British Specification No. 2,703, of 1871, and Stempel's U.S.A. Specification No. 411,360.

Mr. Justice Warrington held that the patent was valid, and that Messrs. Cowlin & Son had infringed Claim 1 by the use of certain piles at Bristol. But as regards Mr. E. Coignet and Mr. G. C. Workman he dismissed the action with costs.

From this decision Cowlin & Son appealed, and the Court of Appeal, consisting of the Lord Chief Justice and Lords Justices Farwell and Buckley, held that the patent was invalid, having been anticipated by Brannon and others. The appeal was reported in CONCRETE of May, 1907.

The tables having been turned in this way, Mr. Hennebique appealed, and the case was heard in the House of Lords last month—*i.e.*, on February 23rd—Mr. L. G. Mouchel having (as reported in these columns) died in the interval.

The case in the House of Lords only occupied a day, and judgment was given in favour of the respondents—that is, Messrs. Cowlin & Son. The Lords of Appeal held that the judgment of the Court of Appeal was right—that the Hennebique patent had been anticipated, and was therefore invalid, that thus no infringement had taken place, and the appeal was dismissed with costs.

Mr. Coignet, who is represented in Great Britain by Messrs. E. Coignet, Ltd. (of which company Mr. Workman is a director), is thus free to continue the construction of piles as originally intended either directly or through licensees.

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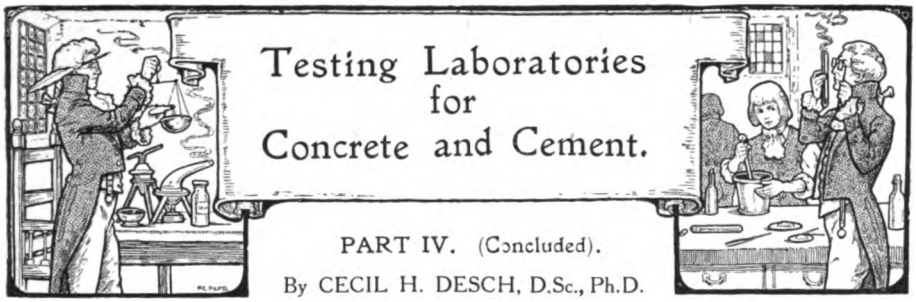

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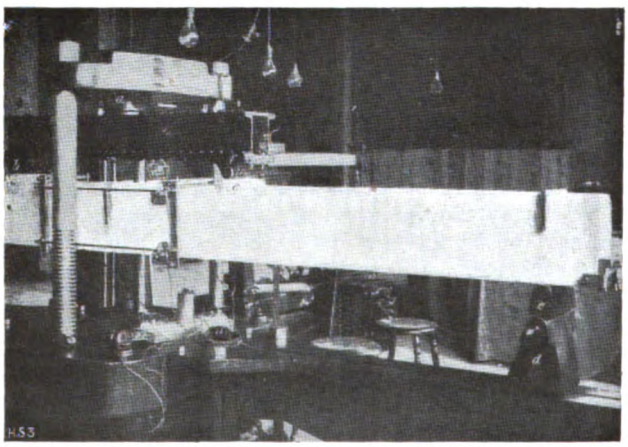

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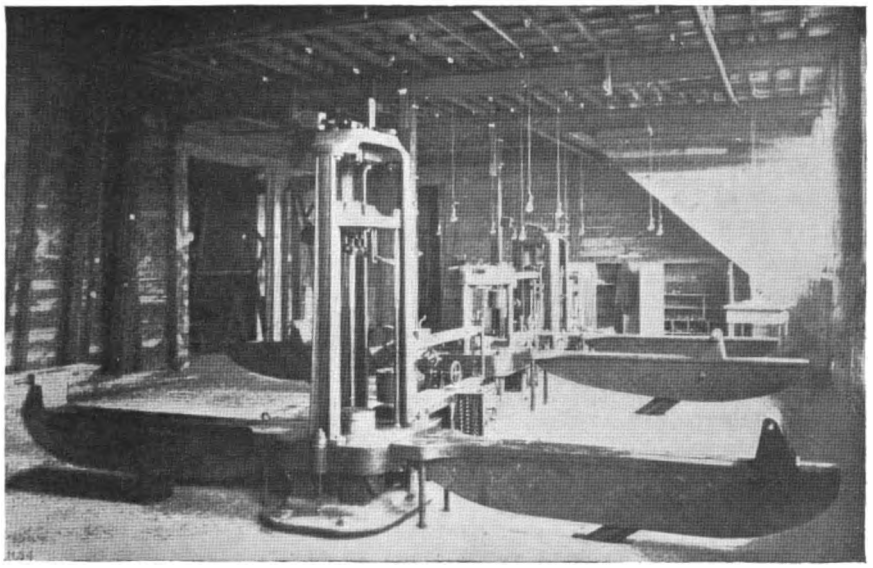

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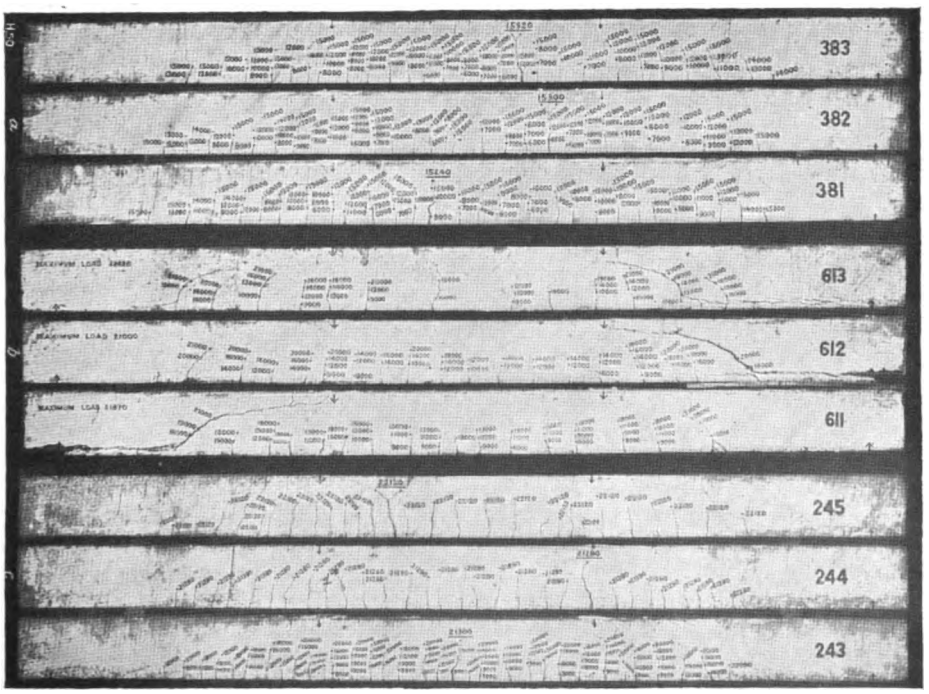
Interior view of Testing Room, Beam Section.



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A chemical laboratory is provided for the complete analysis of the cement, sand, and steel used in the experiments.

Summary.

It will be seen from this series of articles that great variety is to be found in the equipment of the various laboratories in which investigations into the properties of concrete and reinforced concrete are conducted. But whilst it is only possible to carry out investigations of a very comprehensive character in great State-aided institutions of the type of that at Gross-Lichterfelde, it is nevertheless true that much valuable work is done in laboratories possessing a much more modest equipment. A proper co-ordination of the different establishments in which testing can be carried on, avoiding unnecessary duplication and ensuring uniformity of method, is very desirable. Great as is the amount of work performed in connection with reinforced concrete in recent years, much remains to be done in order to clear up points which now remain obscure, to the great disadvantage of those engaged either in designing or in constructing works of this kind.

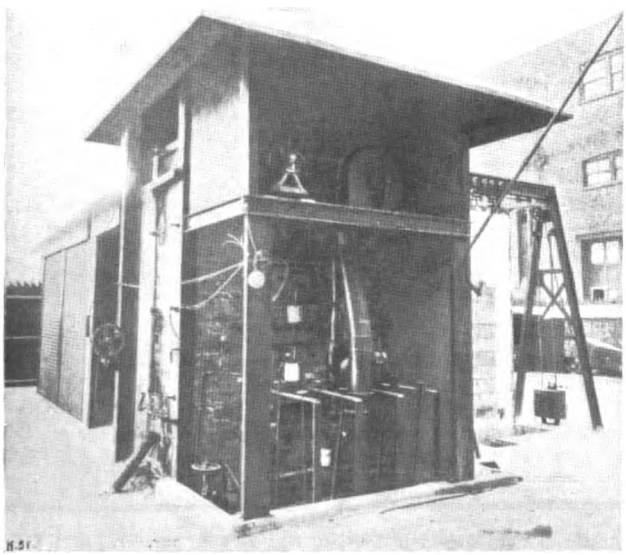

FIG. 4. UNDERWRITERS' LABORATORY, CHICAGO.
Heating Chamber, showing regulating apparatus for gas and air.

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STEEL AND CONCRETE AT THE SELFRIDGE STORES, LONDON

By

S. BYLANDER.

We are in this issue presenting some of the principal constructional drawings of the building known as the Selfridge Stores, which embodies the very latest ideas of a composite structure, comprising steel framing and reinforced concrete. The building is, in fact, a steel frame building in which all the steel work is embedded in concrete, the floors being reinforced concrete floors reinforced with a steel bar.

The building is one of the first, if not the first, in the Metropolis to which the recent amendments to the London Building Act have been applied, and which thus comprises a number of compartments of 450,000 cubic feet each, separated from one another by divisional walls, in which the door openings are also of larger area than was allowable before the passing of the new Act—i.e., 12 ft. by 12 ft.

In this particular case everything appears to have been done that ingenuity could devise to make this building of large cubical extent as safe as possible from the fire point of view, for not only has all the steel framing been well embedded in a suitable concrete, and the reinforcing bars in the reinforced concrete floors duly protected by concrete, but the door openings in the divisional walls have been equipped with modern automatic roller steel shutters, and excellent hydrant and sprinkler systems installed throughout the structure.

In the protection of the steel framing, in the selection of the reinforced concrete floors, and in the specification of the roller shutter doors, the latest experience obtained from the British Fire Prevention Committee's Reports has been applied. For the concrete protecting the steel framing aggregate of small size and Portland Cement of fine grinding have been used, whilst the type of floor applied and the type of roller shutter installed had both passed official fire-tests of four hours' duration, and had obtained the classification of "Full Protection" (Class "B.")

The building does great credit to the designers, Messrs. Burnham & Co., of Chicago, and Mr. Frank Atkinson, F.R.I.B.A., of London, as also to the various other architect and civil engineer specialists who have been called in to advise from time to time. It does equal credit to the contractors, Messrs. Waring and White (1906) Ltd., the engineering department of which firm prepared all the drawings for the steel frame work and floors.

Last, but not least, it does great credit to Mr. Selfridge, who by his perseverance did much, not only to obtain a building of very high qualities, but also to improve the legislative conditions under which it was executed.—ED.

THE new building, known as Selfridge Stores, which has been erected in Oxford Street, London, W., is on a site measuring 250 ft. by 175 ft., and the building occupies the whole site, no central areas or courts being constructed.

The frontages are to Oxford Street, Duke Street, and Somerset Street, of which the former is the most important.

Some small buildings on the other side of Somerset Street are connected to the main building by means of tunnels. These buildings are used generally for packing and despatching goods, and are not referred to as part of the Selfridge Stores in this article.

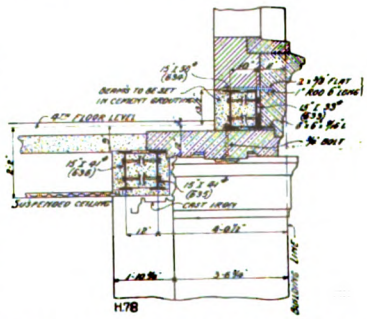

FIG 1. SPANDRIL SECTION AT 4TH FLOOR.

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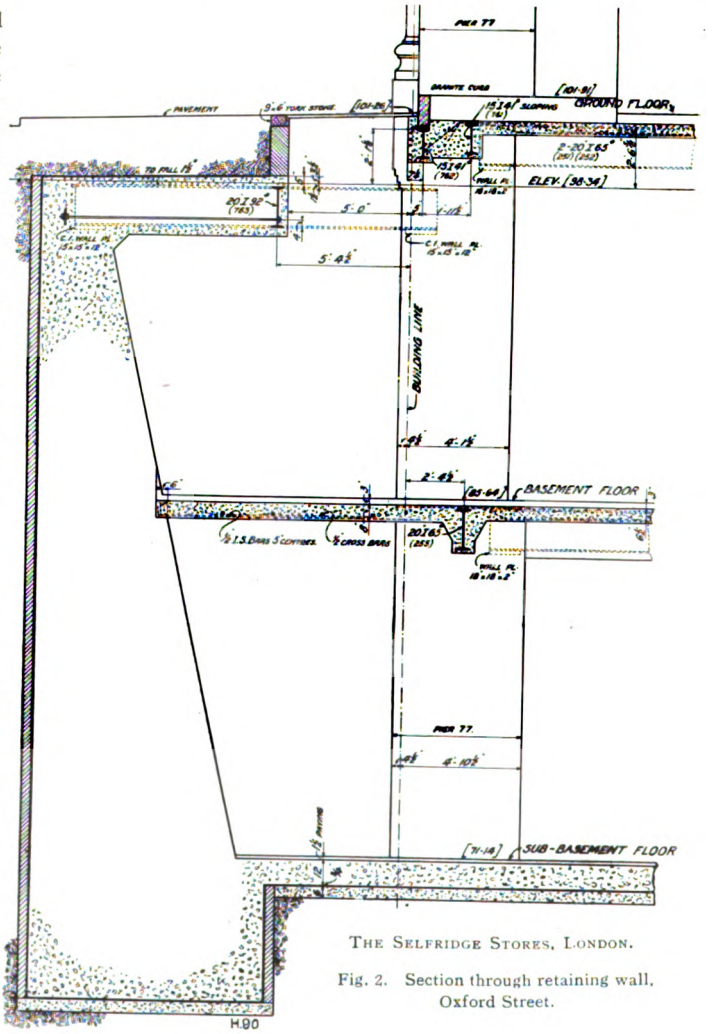
It was originally intended to connect the new building with Bond Street Tube Station on the Central London Railway and run the passenger lifts in the new building down to the same level as the lifts of the tube railway, but permission to carry out this scheme could not be obtained.

The building has three basements and five storeys above ground, the average height of each storey being 15 ft. The total area of floors is 277,500 ft. super. The flat roof is 80 ft. above, and the foundations 60 ft. below street level. The top of the parapet balustrading is 150 ft. above the foundations.

Underpinning.—The work in connection with the foundations was commenced at the earliest possible date, in view of the great depth of the excavations and the underpinning of adjoining walls, and in order to have everything clear and ready for the speedy erection when the delivery of the steelwork commenced. The underpinning of the adjoining building at the west party walls was the first work to be undertaken. The party wall of the store was built from the basement to the first floor level, and bonded into the old adjoining walls for the purpose of strengthening this wall, which was very old and unreliable. The old wall was not counted as part of the thickness of the wall for the store. The combined walls were strutted and underpinned in lengths of about 6 ft. to a depth of about 60 ft. below the street level.



THE SELFRIDGE STORES, LONDON.

Fig. 2. Section through retaining wall, Oxford Street.

One of the old buildings at the corner of Oxford Street and Duke Street was not allowed to be pulled down at the time when the foundations had to be put in for this portion of the new building, so a scheme was prepared for carrying the old building

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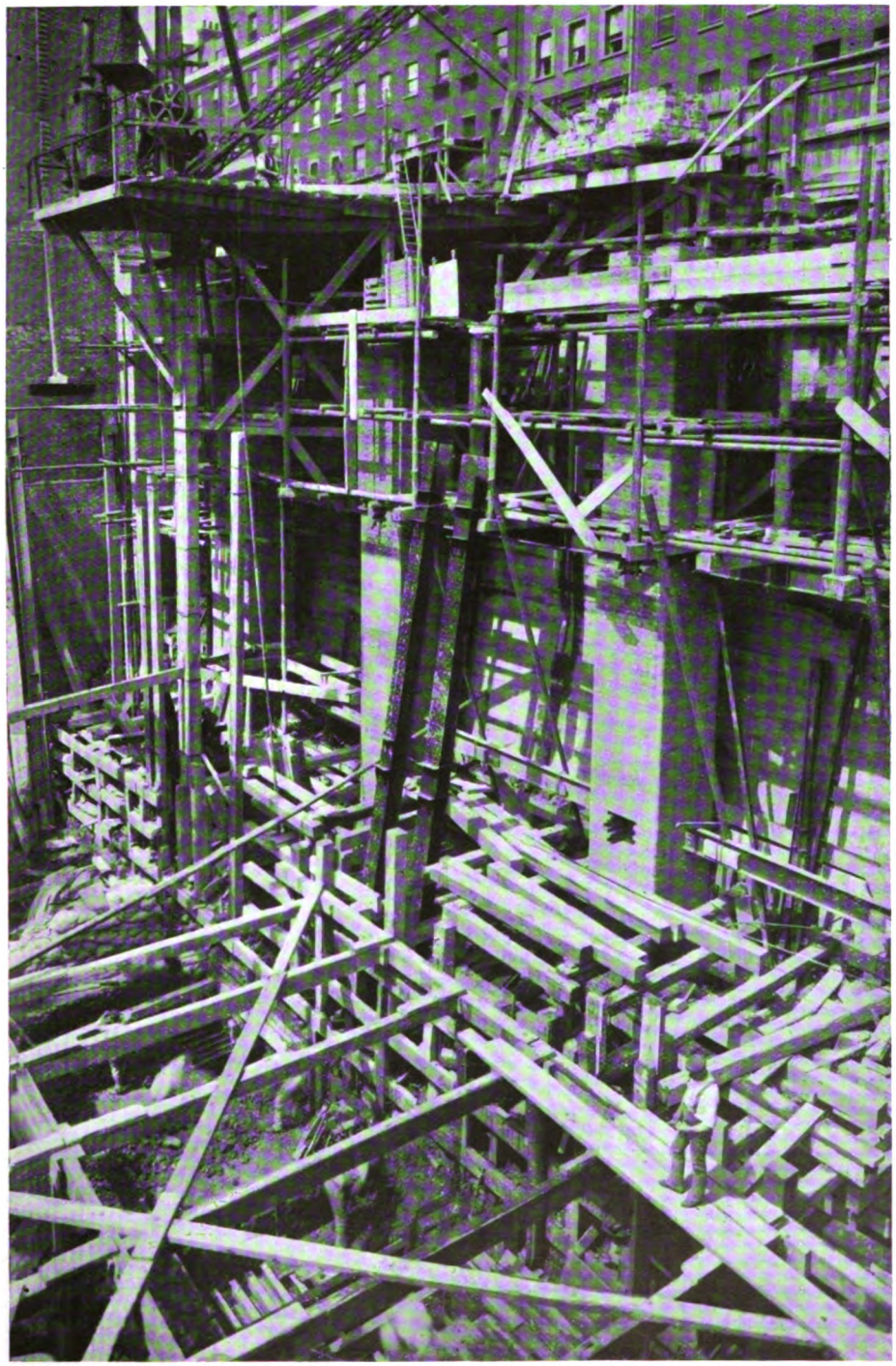

THE SELFRIDGE STORES, LONDON.

Fig. 3. Elevation of reinforced concrete retaining wall to Somerset Street, showing portion of the strutting still left in.

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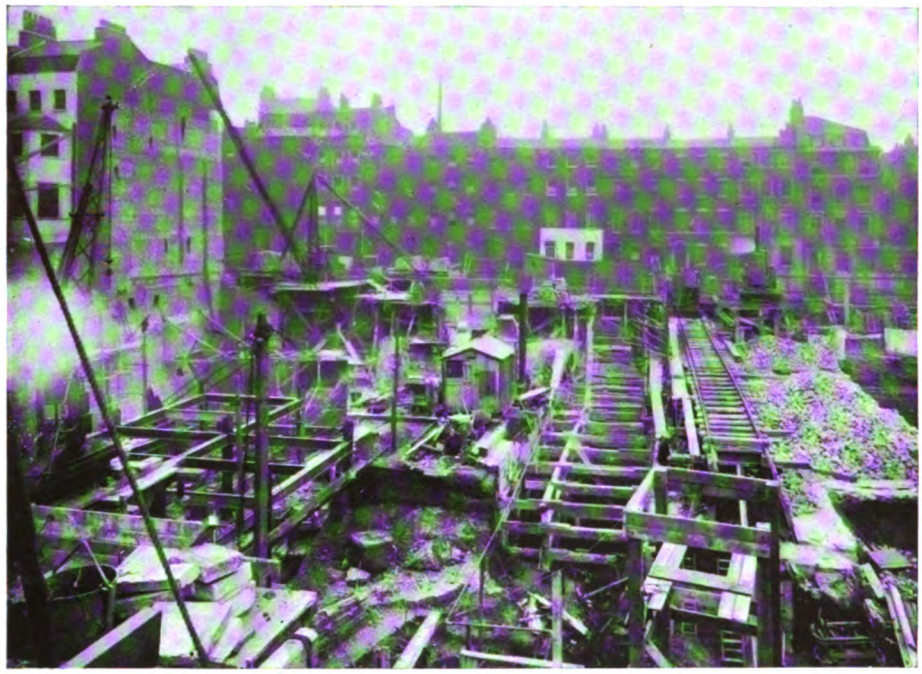
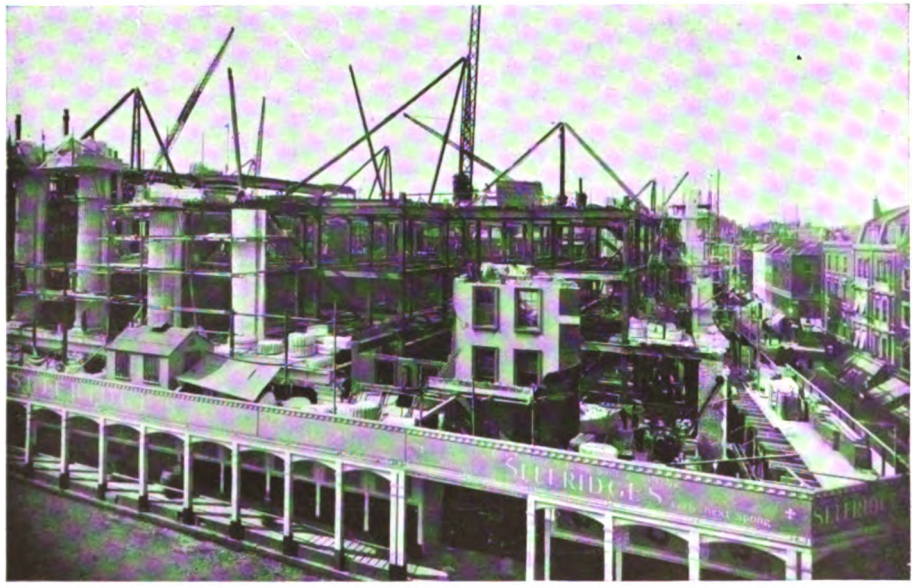


THE SELFRIDGE STORES, LONDON.

Fig. 4. View towards Somerset Street showing excavation in west block partly done, and the steel in sub-basement in place. Track for travelling crane used for excavating and putting in the retaining wall between the west and centre blocks.



THE SELFRIDGE STORES, LONDON.

Fig. 5. Corner of Duke and Oxford Streets, showing the old building still intact up to the third floor.

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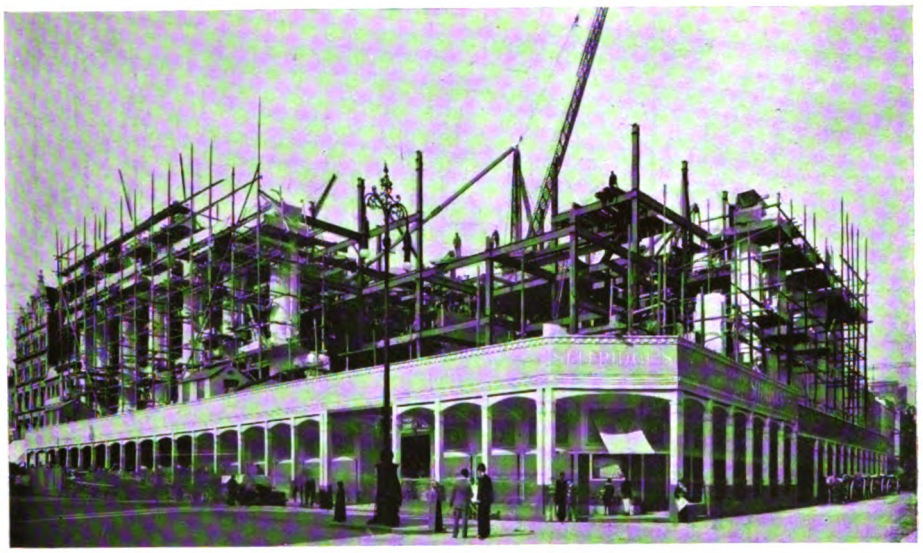
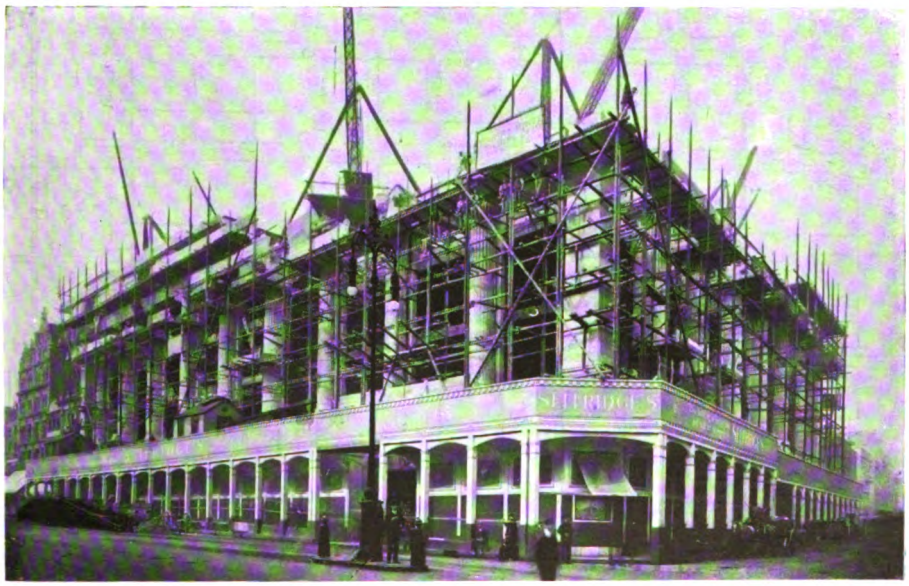
(which was four storeys above ground) on steel needle beams while the excavations for the new basement were made, and large foundations put in below the existing building.



THE SELFRIDGE STORES, LONDON.
Fig 6. Steelwork erected to the third floor, except last bay. No walls yet erected above ground floor.



THE SELFRIDGE STORES, LONDON.
Fig. 7. Steelwork and stonework erected complete up to the fourth floor level.

This scheme, however, was not carried into execution, as permission was granted to pull down the old building before the work was begun. The rapid progress of construc-

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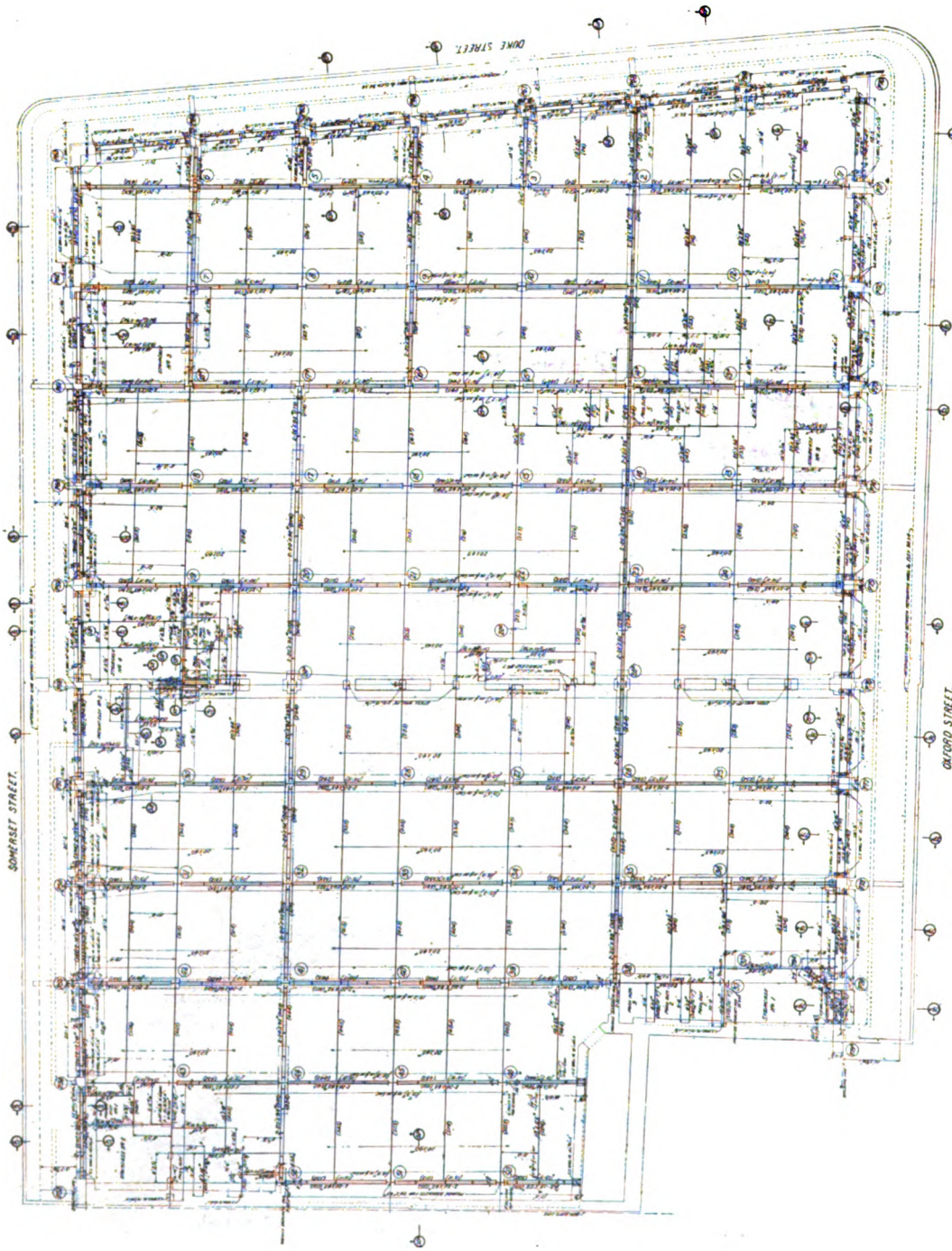

THE SELFRIDGE STORES, LONDON. Fig. 8. Ground floor framing plan.

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tion of this portion of the building can be seen from the photographs taken on August 17th, 1908, September 17th, 1908, and October 2nd, 1908 (see *Figs.* 5, 6, and 7). The last photo shows the steelwork and stonework erected complete up to the fourth floor level.

THE SELFRIDGE STORES, LONDON. Fig. 9. General view of constructional steelwork.

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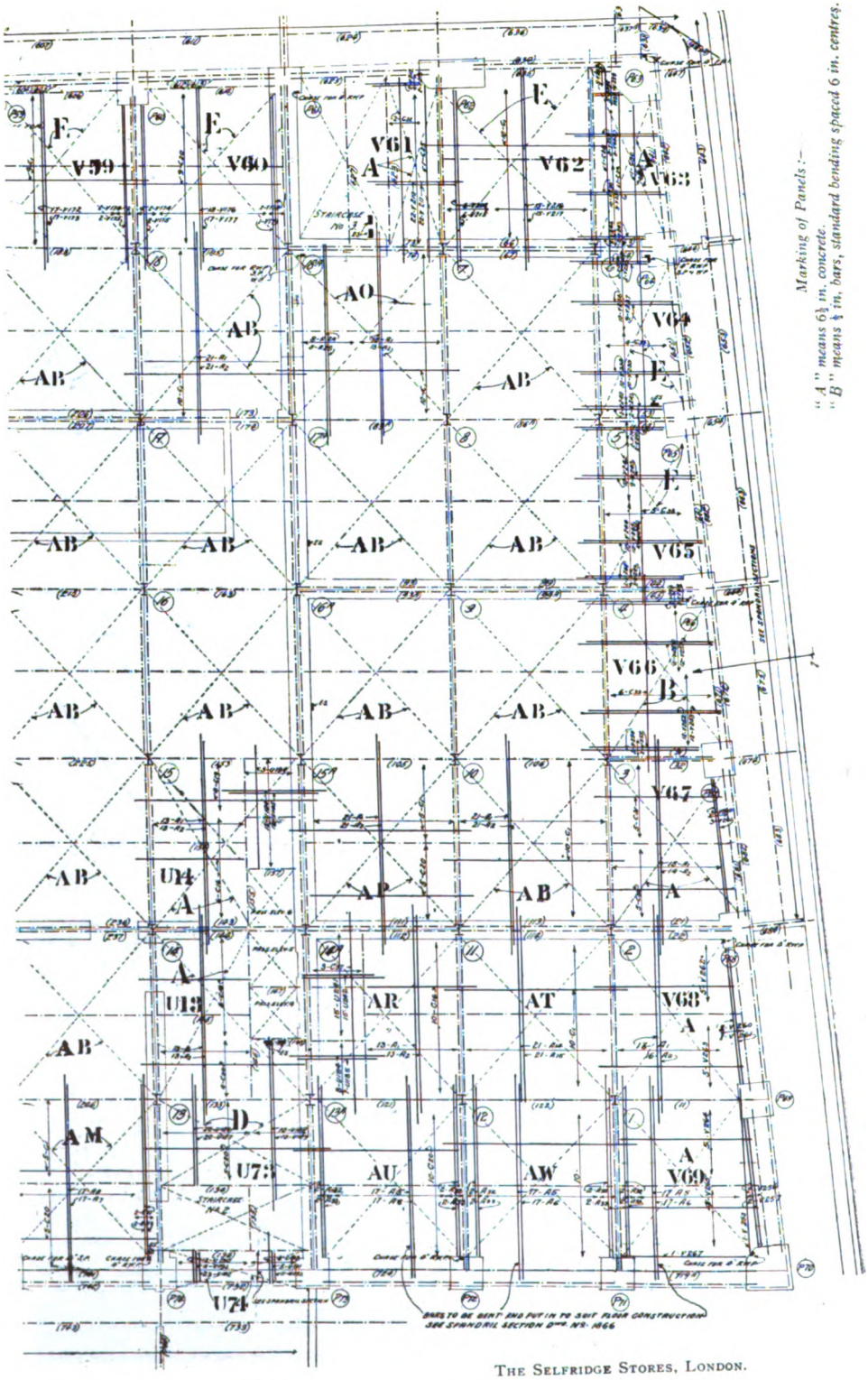

THE SELFRIDGE STORES, LONDON.

Fig. 10. Part plan of ground floor, showing construction of reinforced concrete floor.

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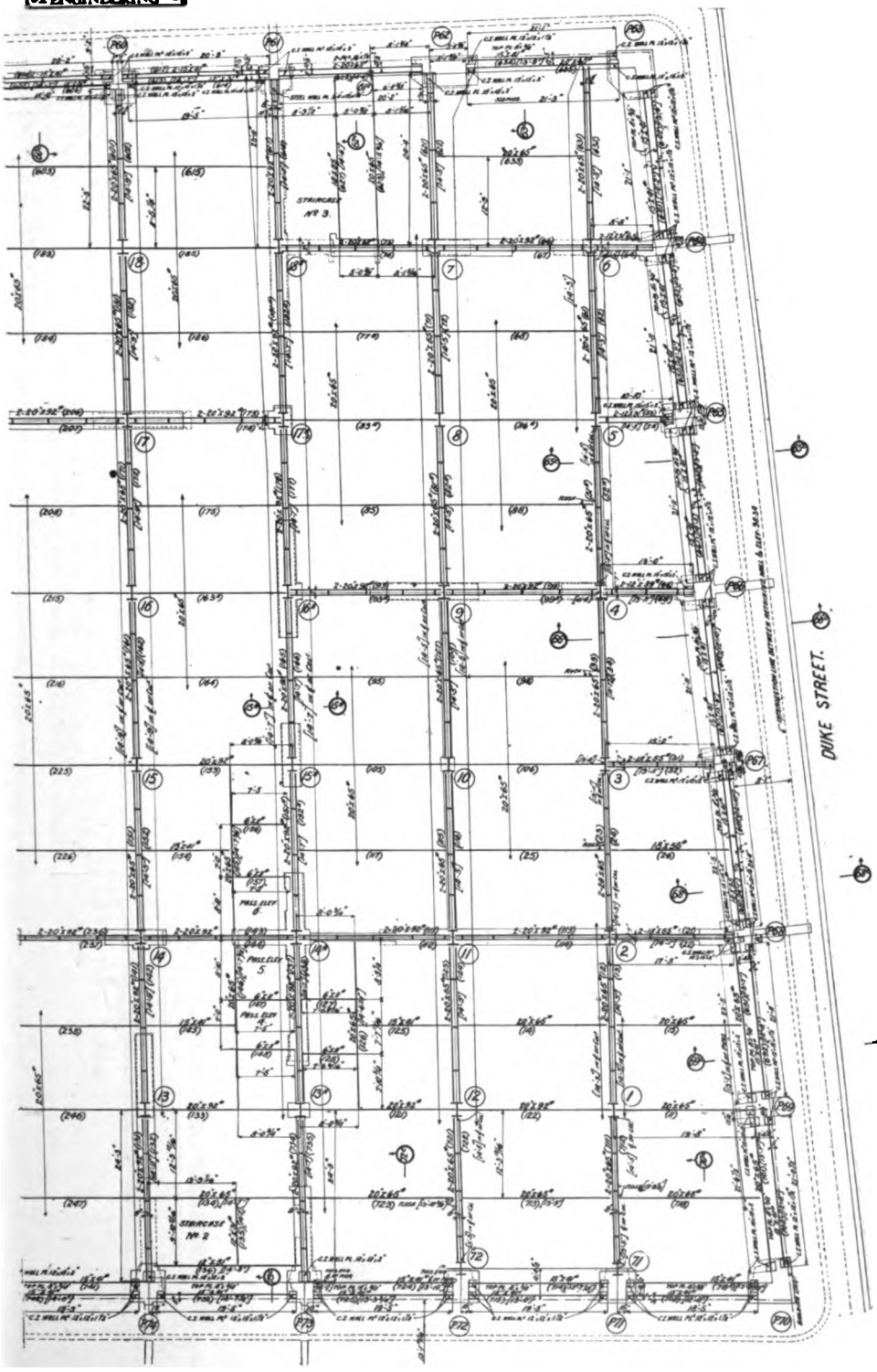

C THE SELFRIDGE STORES, LONDON. Fig. 11. Part of ground floor framing plan. 17

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Retaining Walls.—All the retaining walls were built in trenches excavated before the excavation of the main portion of the site was proceeded with. With the exception of the retaining wall to Somerset Street the retaining walls are built in ballast concrete without reinforcement. The retaining wall to Somerset Street opposite that part of the building which has a third basement is built in reinforced concrete, and is 60 ft. high. This wall is reinforced with light channel irons, spliced where required, and also with "Indented" steel bars.

For the main reinforcement the bars are $1\frac{1}{4}$ in. sq. The horizontal reinforcement is placed on both sides of the walls—$\frac{3}{4}$ in. bars 2 ft. apart, centre to centre, to prevent cracks.

The base of the wall is 25 ft. wide measured from back of the wall, and is reinforced top and bottom with "Indented" steel bars, and the load from the piers is spread by means of 20 in. deep steel beams. The toe of the walls forms the foundations for the brick exterior piers, which carry walls and floors above. The resultant pressure per square foot on the ground under this wall is the same as to the other foundations. The length of the toe has been proportioned accordingly. The trench for this wall was 100 ft. long, 25 ft. wide, and 60 ft. deep, and the whole length was constructed at the same time. The strutting consisted of 10-in. by 10-in. pitch pine struts spaced 6 ft. centre to centre horizontally and 6 ft. centre to centre vertically.

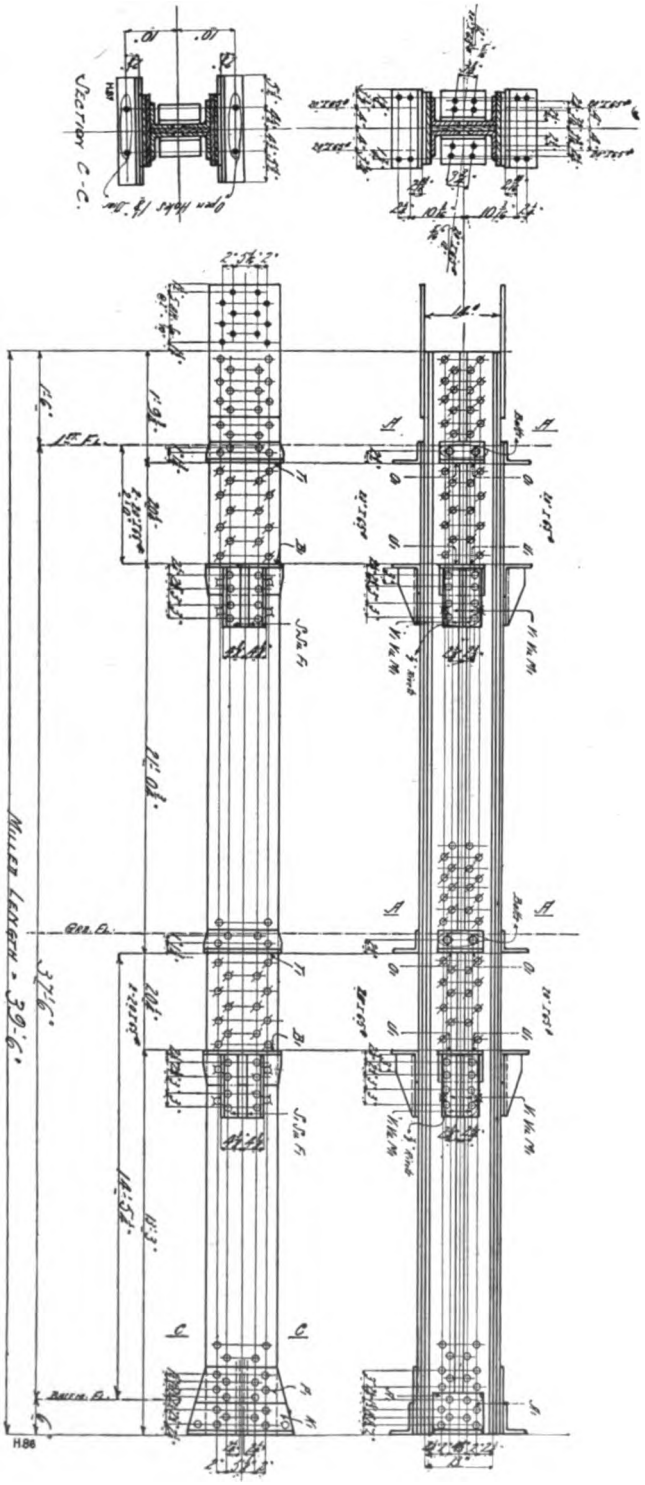

Fig. 12. Shop details of Tier B. Column No. 8. Bill of Material is shown in Fig. 19.

THE SELFRIDGE STORES, LONDON.

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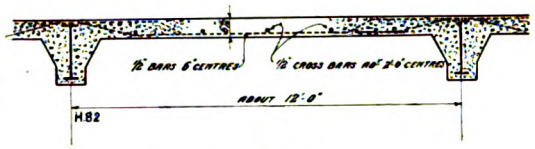

SECTION OF
REINFORCED CONCRETE FLOOR
Fig. 13.

Fig. 2 shows the construction of the centre party wall, the lower portion of which also acts as a retaining wall.

Fig. 3 shows the elevation of reinforced retaining wall to Somerset Street; a portion of the strutting not yet taken out.

The Setting out of the Building.—The setting out of the building is very simple. The columns are placed in straight lines, and the distance between centres is 24 ft. one way, and 22 ft. the other. The centre lines of the columns make an angle of 87 deg. with the building line at Oxford Street, and are parallel with the centre

THE SELFRIDGE STORES, LONDON.
Fig. 14. Laying the "Indented" bar reinforcement.

party wall. Although on the skew, all panels are made alike as far as possible, considerably reducing the cost and the number of drawings required for details, etc. The dimensions were given on the plans, and the centres set out accordingly on the site.

Theodolite was used for setting out angles and straight lines for the column centres and building line. The site survey was made before the drawings were prepared, and all dimensions given thereon.

The levels of pavement, and also the building datum, were given on the site plan with reference to the British Ordnance datum. The level of steelwork was given from the respective floor levels, and not from British Ordnance datum.

Figs. 8, 11, and 23 show the ground floor and roof plans, illustrating the setting out of the columns and beams, the numbering of the different pieces, and dimensions and levels.

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WARING & WHITE (1906) L^D.
1A COCKSPUR ST.,
LONDON, S.W.

Job No. 13 Made by [illegible] Checked by [illegible] In charge of [illegible]

Number of bars wanted	Size of bars	Length of bar	Mark	Between bar sheet No.	N = Not bent at ends B = Bent at ends
85	½"	30'-3"	A9	3106	B
16	½"	26'-7"	A10	3106	B
16	½"	20'-10"	A11	3106	B
14	½"	20'-4"	A12	3106	B
14	½"	18'-8"	A13	3106	B
19	½"	30'-8"	30-8	3107	N
19	½"	28'-9"	28-9	3107	N
~~52~~	~~½"~~	~~30'-10"~~	~~A30~~	~~3104~~	B
85	½"	28'-0"	A7	3106	B
126	½"	22'-11"	C9	3102	B
10	½"	16'-8"	C12	3102	B
			C13	3102	B
10	½"	24'-0"	C14	3005	B
12	½"	15'-8"	C16	3102	B
24	½"	23'-8"	C20	3103	B
17	½"	28'-10"	Y118	3105	B
17	½"	22'-1"	Y119	3105	B
18	½"	29'-5"	Y124	3105	B
17	½"	22'-8"	Y125	3105	B
17	½"	25'-1"	Y128	3105	B
17	½"	23'-3"	Y129	3105	B
19	½"	17'-11"	Y144	3122	B
20	½"	12'-3"	Y145	3122	B
12	½"	26'-0"	Y148	3121	B
17	½"	27'-2"	Y172	3120	B
17	½"	25'-4"	Y173	3120	B
18	½"	27'-9"	Y176	3119	B
17	½"	25'-11"	Y177	3119	B
22	½"	17'-11"	Y210	3117	B
21	½"	12'-3"	Y211	3117	B
15	½"	32'-2"	Y216	3118	B
15	½"	28'-3"	Y217	3118	B
10	½"	13'-8"	Y230	3116	B
10	½"	14'-4"	Y236	3115	B
10	½"	15'-6"	Y238	3115	B
10	½"	15'-9"	Y239	3115	B

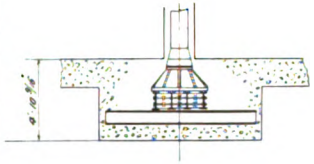
SELFRIDGE STORES
GROUND FLOOR
ORDER LIST FOR I.S. BARS

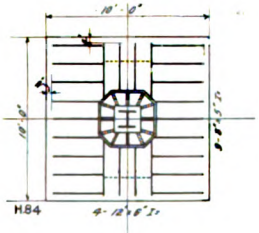
SHEET No. 2557

H.70

FIG. 15.

Characteristic Working Instruction Sheets.





TYPICAL PLAN & SECTION OF GRILLAGE FOR COLUMNS.

THE SELFRIDGE STORES, LONDON.

Figs. 15, 16, 17.

WARING & WHITE (1906) L^D.
1^A COCKSPUR ST.
LONDON S.W.

Job No. 13 Made by [illegible] 18th March 08 Checked by [illegible] 22nd Mar. In charge of [illegible]

Panel Mark	Panel Between beam No.	Shape of bar Y116	Y117	Y140	Y141	Y142	Y143	U130								
		Number of bars wanted														
V46	463-464	8	8													
V52	435^R-435			6	6	2	1									
V53	439-541							11								
		Y272	Y273	Y274	Y275	Y276	Y277	Y278	Y279	Y280	Y281	Y282	Y283	Y284	Y285	
V39	463-464	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
		C1	Y118	Y119	Y128	Y129	Y196	Y197	Y124	Y125	Y152	Y153				
V54	553-423	8	17	17	2	2	3	3								
V55	565-313	8			2	2			19	17	2	2				
		C1	Y128	Y129	Y180	Y181	Y182	Y183	Y132	Y133	Y155	Y157	Y152	Y158		
V56	573-303	8	17	17	3	3	2	2								
V57	582-305								5	5	1	3	2	3		
		C17	C18	Y144	Y145	Y146	Y147	C1	Y170	Y171	Y172	Y173	Y174	Y175		
V58	594-197	2	1	19	19	3	2									
V59	606-183							9	2	2	17	17	2	2		
		C1	Y270	Y271	C20	Y174	Y175	Y176	Y177	Y178	Y179					
V50	503-504	6	21	21												
V60	614-135				9	2	2	18	17	2	1					
		C22	C23	Y210	Y211	Y212	Y213	C1	Y214	Y215	Y216	Y217				
V61	625-73	2	1	22	22	2	2									
V62	635-66							10	6	6	15	15				
		C28	C29	C30	Y223	Y225	Y226	Y227	Y228	Y229	Y230	Y231	Y232	Y233	Y246	Y247
V63	635-63	1	1	1	5	1	1	1	1	1	10	9	8	8	2	2
		C33	Y234	Y235	Y236	Y237	Y238	Y239	Y240	Y241	Y242	Y243	Y244	Y245	Y246	Y247
V64	64-53	4	2	2	10	9	10	10	2	2						
V65	54-44	5							2	2	10	9	10	10	2	2
		C33	Y250	Y251	Y252	Y253	Y254	Y255	Y248	Y249	B1	B2	C34	C12	Y260	Y261
V66	45-31	6	11	12	12	12	3	2	3	2						
V67	32-21										15	14	5	5	3	3

SELFRIDGE STORES
GROUND FLOOR
BILL OF MATERIAL FOR I.S. BARS

SHEET No. 2607

H.80

FIG. 17.

CONCRETE

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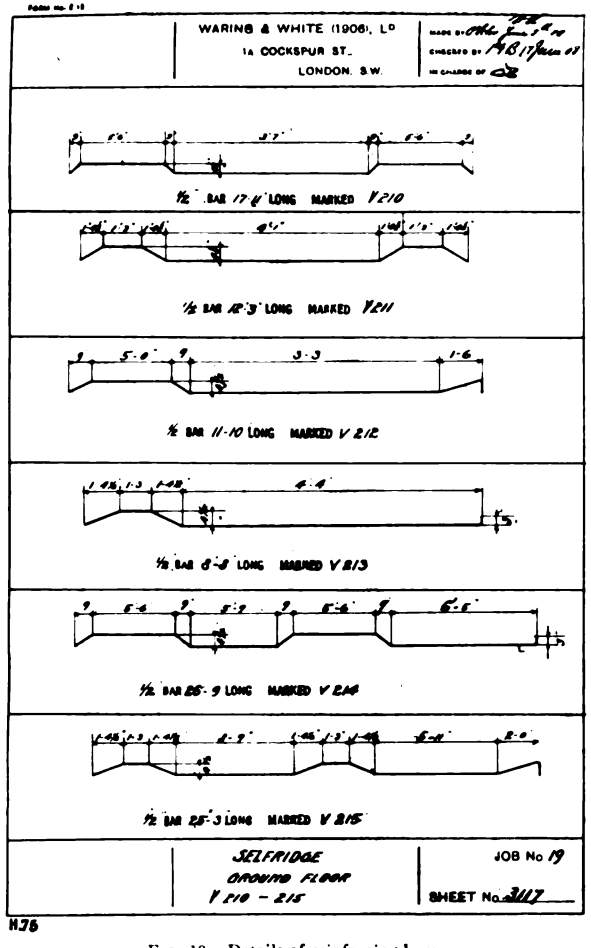

FIG. 18. Details of reinforcing bars.

Characteristic Working Instruction Sheets.

MAKE 1 PIECE
Marked "B" 8

Bill of Material for one Column				
No. Wanted	Mark	Description	Section	Length
1		Web Plate	13" x ⅜"	39'6"
4		Angles	5½" x 5½" x ½"	39'6"
2		Flange Pl.	14" x ½"	39'6"
2		"	14" x ⅜"	38'0½"
4	T1	L Brackets	7½" x 4" x ⅝" x ⅜"	14'4"
4	B1	"	6½" x 6½" x ⅜"	14'4"
4	O1	"	6" x 4" x ⅜"	8½"
4	U1	"	6" x 6" x 5/16"	8½"
2	A1	"	8" x 4" x ⅜"	11"
2	K1	"	6" x 4" x ⅜"	1'8"
8	S1 S1a	Stiff Lt.	5½" x 3½" x ⅜"	11½"
8	V1 V1a	"	4 3/16" x 4 3/16" x ⅜"	11½"
4	F1	Fillers	8¾" x ⅜"	6"
4	M1	"	8⅝" x 5/16"	6"
2	P1	Gusset Pl.	13" x ½"	1'8"
2		Splice Pl.	14" x ⅜"	2'2"

H.88

Fig. 19. A Bill of Material for column detail shown in Fig. 12.

THE SELFRIDGE STORES, LONDON.

Figs. 18, 19, 20.

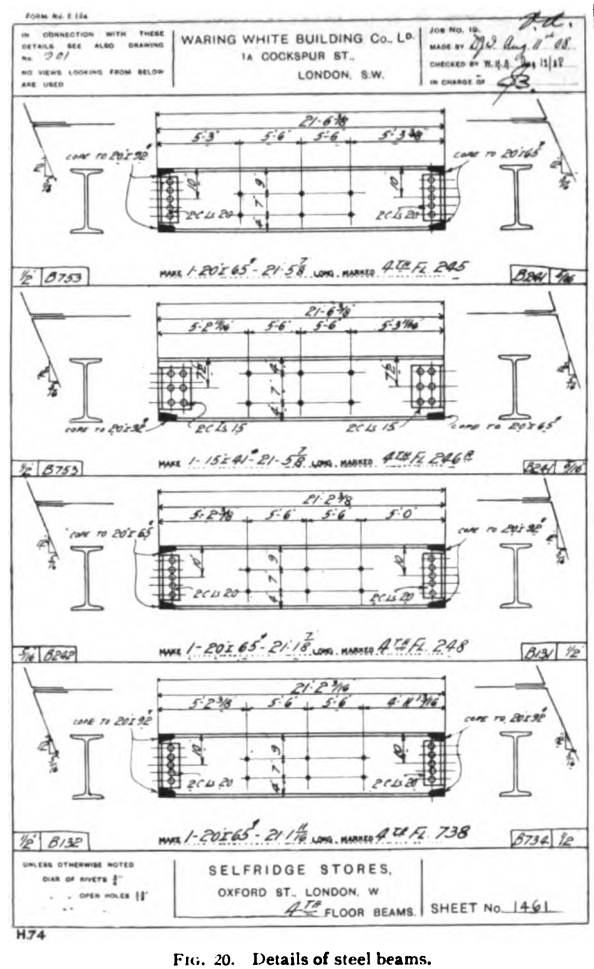

FIG. 20. Details of steel beams.

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The ground floor has a uniform slope from west party wall down to Duke Street of 2 in. in 22 ft. in order to avoid steps at the entrances from the street.

All levels of connections between beams and columns are given on the steelwork plans (see ground floor framing plan). All divisions—or cross walls—have been placed central with the steel columns and a set off made on both sides of the wall as the thickness of the wall is reduced.

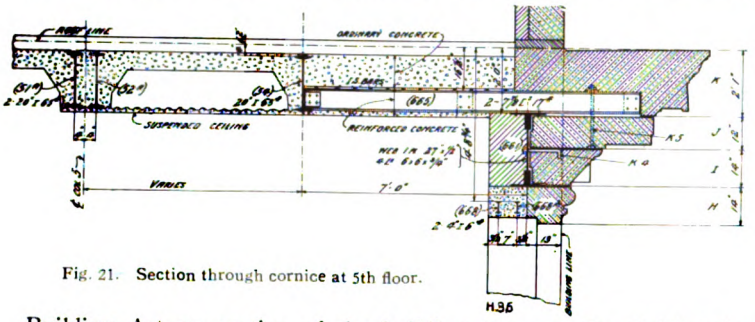

Fig. 21. Section through cornice at 5th floor.

Cubical Contents.—In order to comply with the London Building Act no portion of the building between the divisional walls is of greater cubical content than 450,000 ft. cu., taking the whole height of the building as if there were no fire-resisting concrete floors.

The size of the door openings in the party walls are made 12 ft. by 12 ft., special permission being granted by the London County Council.

General Design. — All the interior walls, except the west party wall, are carried on steel framing, and the floors are built independent of the walls. The exterior wall to Oxford Street and Duke Street is faced with Portland Stone and the backing is blue brick for piers. The frontage to Somerset Street is brick. One of the most noticeable features of the building is the great distance between the columns, and the omission of brick or stone mullions. The window area, therefore, is very large, and good lighting has thus been obtained, also the weight of the exterior walls has been materially reduced. The window frames and mullions are of cast iron.

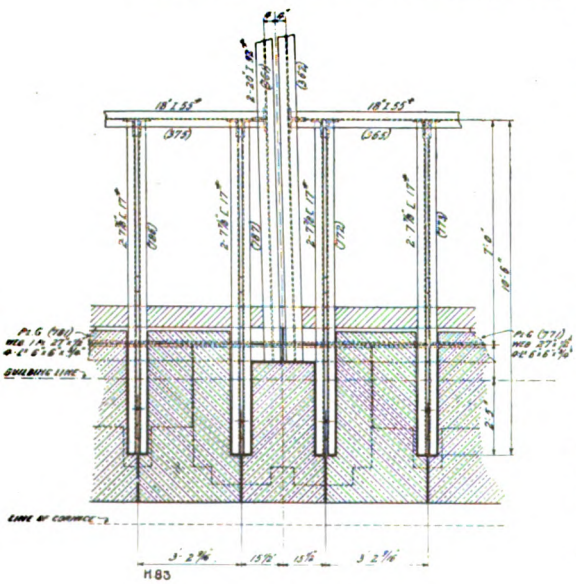

Fig. 22. Plan of cornice at 5th floor.

Constructional Steelwork.—There are about 3,000 tons of steel in the building, which was erected at the rate of about 125 tons per week.

The design and erection of the steelwork and also the preparation of shop drawings was carried out by Waring and White (1906), Limited.

For the carrying out of the steelwork, retaining walls, foundations, and mechanical appliances only, about 12,000 blue prints were required, of which 2,500 were 40 in. × 27 in. in size, not including architectural drawings, drawings for sprinkler and heating systems, etc. Every piece was marked with an identification number, as well as the Mill's blow or melt number and the inspector's mark of approval.

All the steel, except rivets and bolts, was made to the following specification :—

Tensile strength : 60,000 to 70,000 lb. per sq. in. Elongation : At least 20 per

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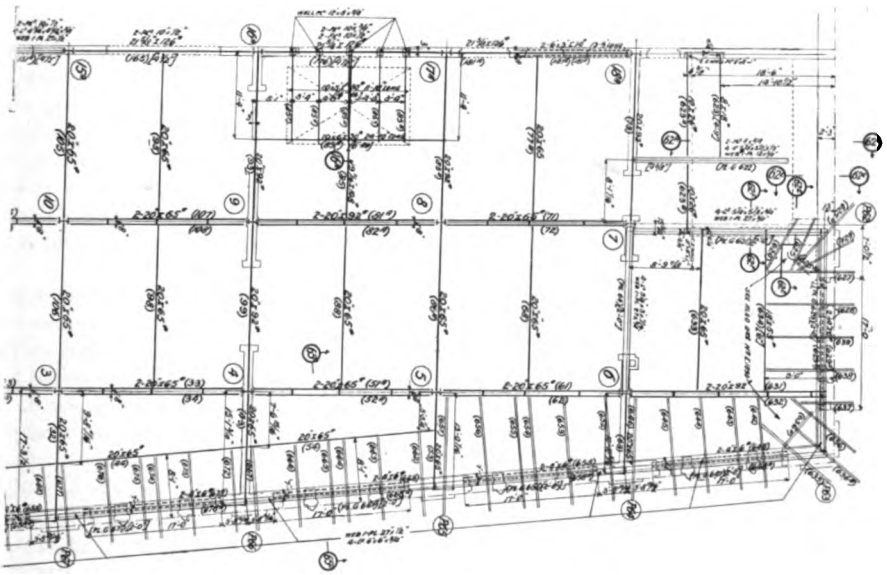
cent. in 8 in. on standard test piece. Bending tests, percentages of phosphorus and sulphur were also specified.

The inspector was resident at the place of manufacture and inspected every piece of material. He also made all the specified tests for the different portions of the work and reported the results to the engineer.

The steelwork was not fitted together in the shops, but made to detail drawings —no wooden templates were used. By means of careful checking of the drawings, inspection of the finished material as to dimensions and accurate setting out on the site, the steelwork fitted exactly when erected, and no drilling or cutting was required.



THE SELFRIDGE STORES, LONDON.
Fig. 23. Part of roof framing plan.

The cranes used for hoisting and erecting the steelwork were supported on the steel framing and raised from floor to floor as the erection proceeded, and the method of three tower gantrys was not used for supporting the cranes. *Fig.* 9 shows the steel skeleton partly erected. It may be noticed that a great quantity of "Indented" steel bars for the floors already bundled and labelled are temporarily stored on the steelwork.

Columns. — The columns are set on cast-iron bases, generally 1 ft. 6 in. high and 3 ft. 6 in. square on plan. The top of the bases and the ends of steel columns are planed in order to obtain a perfect bearing. No cap plates are used between the different tiers.

The columns are built up of angles and plates, and the overall dimensions are about 14 in. × 14 in.

Eccentric loading has been avoided as far as possible.

The steel columns are encased in concrete, and the architectural columns were finished in plaster. The outside dimensions of the steel columns had to be made relatively small to suit the diameter of the architectural columns.

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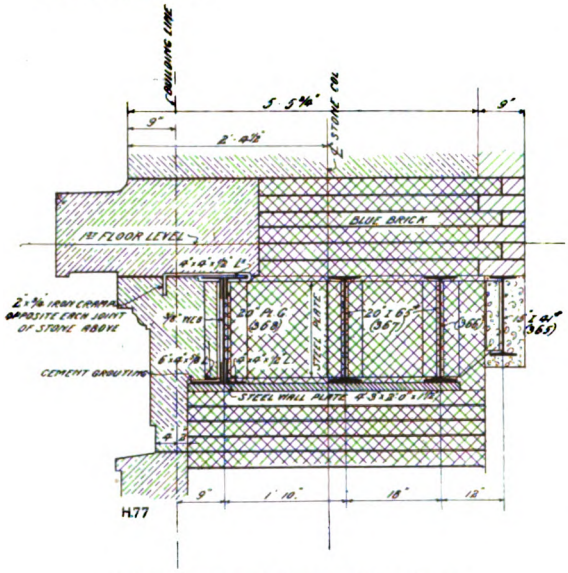
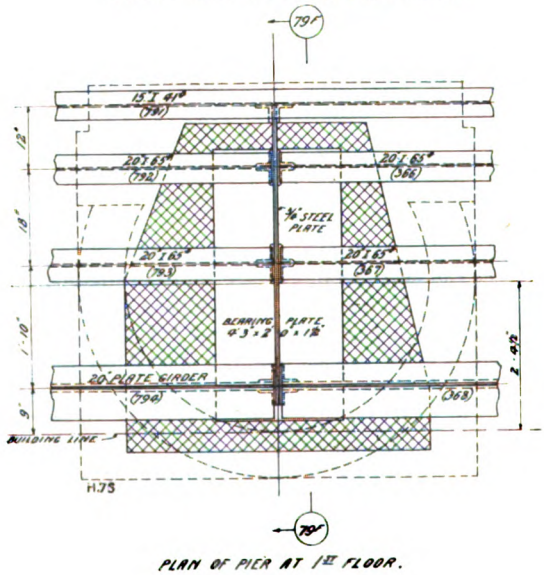
The steel columns were generally made in two-storey lengths, and spliced about 18 in. above floor level. A typical column detail is shown in *Fig.* 12.

The steelwork is riveted throughout, and bolts are not used except where rivets cannot be used. Beams and columns are connected by means of splice plates riveted after erection.



SECTION THROUGH PIERS AT FIRST FLOOR.



FIGS. 24 AND 25.

The stiffeners under the girders are made strong enough to carry the total load, and the top brackets are only for stiffening and bracing. The outstanding leg on the stiffeners was cut on the skew to suit the plaster cap on the column.

Beams. — The floor framing is shown on the ground floor plan and roof plan, *Figs.* 8, 10, and 11. All the beams for standard panels are 20 in. deep. The girders carrying the floor beams consist of two 20-in. I beams. The walls are also carried on two 20-in. I beams, but of extra heavy weight.

This framing is very economical and suitable for good connections and rapid construction. The spacing of the floor beams is 12 ft., dividing the 24 ft. by 22 ft. bay between the columns into two equal floor panels 22 ft. by 12 ft.

Floors.—The floors are constructed in reinforced concrete, and consist of 6½-in. flat slab single construction, 12-ft. span for standard panels.

The reinforcement consists of ½-in. "Indented" steel bars spaced 6 in. centre to centre, and cross bars ½ in. square spaced 2 ft. centres. The bars are covered on the underside with 1-in. concrete. (The steelwork is covered throughout with at least 2 in. of concrete.)

The fireproofing is held in position on the lower flange of the girders, and round the columns with 3-16 in. diam. wire reinforcement spaced 9 in. centres.

Mixing of Concrete.—The concrete was made up as follows: 1 part Portland cement of the "Hilton Anderson" Brand, 2 parts sand, 2 parts broken brick, 2 parts of pumice clinker, all to pass a ¾-in. mesh.

The concrete was mixed in a batch machine mixer, and the plant consisted of

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platform for the aggregate, hoppers for the different materials, measuring device for sand, stone crusher, concrete mixer, and a shoot for the finished concrete.

The weight of cement in each bag was so apportioned as together with the aggregate to form one batch of concrete in the mixer.

The sand was measured and mixed by hand with one bag of cement. The sand and cement mixture was then put into the hoppers side by side with hoppers containing broken brick and clinker. The clinker and brick were first mixed, while a fixed quantity of water was added. The sand and cement mixture was then put into the mixer and the whole well and properly mixed. The concrete was transported in wheel-barrows to the spot where it was to be spread on the building, or hoisted by temporary lift to the different floors.

The aggregates were inspected on arrival at the site, and all unsuitable material rejected.

Centering. — The centering was designed in the office, and made in such a manner that it could be bodily removed (when the concrete was set) to another part of the building. The centering was thus used several times without any alteration, thereby saving considerable time and expense.

The material was ordered and the centering constructed ready for placing in position before the steelwork was erected. As soon as required the centering was hoisted by the steel erection cranes to the floors and into the positions where it was required.

On account of ready centering, ready bent bars, and large concrete mixing plant, the construction of the floors was carried out very expeditiously, at the rate of 2,000 yds. per week.

The holes for sprinkler drop pipes, electrical conduits, heating pipes and ventilation shafts were left when the floors were being laid, and thus no cutting of floors was done afterwards, except in a few cases where alterations made it necessary. The spaces around the pipes were grouted up with cement mortar, and sleeves were provided for the heating pipes.

Reinforcement. — 250 tons of "Indented" steel bars have been used for the floors and retaining walls. All the standard reinforcing bars were bent to the required shape in the mill; special shaped bars were bent on the site, but always according to complete detail drawings.

The construction of the floors, bending and shaping of bars is distinctly shown on the drawings, reference marks and numbers being used for the assistance of the workmen. The principle of showing everything complete on the drawings was followed throughout, and the foremen on the job were not called upon to decide any point of the construction, but simply to carry out the work as shown on the drawings and stated in the specification.

The method of placing the bars is shown on ground floor plan, *Fig.* 10. From this plan is prepared the bill of material, giving sizes and number of bars for each panel, and also the distinguishing mark. The bill of material (*Fig.* 17) was used for preparing the mill order list for the bars, and was also used by the workmen on the site when selecting bars for each panel.

The bars were wired together in bundles before despatch from the mills, and a metal tag attached giving the identification mark. *Fig.* 15 shows the Mill Order List, giving number and size of the bars, lengths, and also particulars for bending. Cutting list was prepared in special cases where standard bars could not be used. The object of the above method was to reduce the work on the site, and to give the Foreman Floor Layer definite particulars of construction, and facilitate checking that all bars were actually placed as shown on the drawings. *Fig.* 18 shows detail sheet for bending the bars. *Fig.* 20 shows a typical shop drawing for beams.

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Staircases.—The staircases are constructed in reinforced concrete, projecting beams, and thin slabs being generally used. The stairs are supported at each floor level on steel beams which form part of the floor framing. The steps and landings have granolithic finish.

There are five main staircases running the whole height of the building. They are built next to the exterior walls, with exit direct to street. The width of the stairs is 4 ft. 6 in.

Cast iron exterior fire-escape staircases are not provided.

Loads and Stresses.—The foundations have been apportioned in such a manner that each square foot of the ground has a uniform load of 5,000 lb. per sq. ft. All piers and steel columns are carried on steel beam grillages. Typical plan and section is shown in *Fig.* 16.

The floors are calculated for a safe load of 220 lb. per sq. ft. Maximum compressive stress for the columns is 12,000 lb. per sq. in. Extreme fibre stress for steel beams is 16,000 lb., and riveted girders 15,000 lb. Maximum sheer 10,000 lb. per sq. in.

Special allowance has been made for eccentric loading.

Partitions.—The partitions are of concrete blocks 3 in. thick set in cement mortar.

For partitions, such as enclosures to lift shafts, steel framing is used around doors and window openings, and the concrete blocks are fitted in between the steel frame, this forming a stiff screen without any wood built in, which, in case of fire, would be liable to burn out and cause the whole partition to collapse.

Doors. — The doors in the divisional walls are of the roller shutter type running in protected grooves.

Lifts. — A quick and convenient means of communication between the different floors is provided for by means of 9 passenger lifts, electrically driven, and run at a speed of 300 ft. per minute. Each lift cage is approximately 6 ft. square. Safety appliances are provided to prevent accidents. In case a lift should stop between two floors the passengers can enter the adjoining lift by a side door and immediately be taken to the floor level. The goods are handled by two freight lifts.

Fire Appliances.—The installation for fire prevention and extinction is particularly elaborate, every room or part of the building is provided with automatic sprinklers of the "Grinnell" type. The sprinklers are placed in the ceiling about 10 ft. apart. In case of fire the safety metal in the sprinkler head is melted by the heated air and the sprinkler starts immediately to spread water in all directions. There are 1,350 sprinklers, and 32,000 ft. run of piping.

At every floor each staircase is provided with a double fire hydrant, four coils of hose, and the necessary couplings, placed inside a glass door in recesses formed in the brickwork. There are in all 36 double hydrants completely fitted up and ready for use at any moment, 6,600 ft. of 2½-in. hose, 148 pairs of couplings, 72 branch pipes, and five street preparations for the London Fire Brigade to pump into the hydrant system.

The water for the sprinklers and hydrants is supplied from the high-pressure Metropolitan water main, and the pressure is further raised by injectors driven by hydraulic power.

Every room is fitted with an automatic fire alarm, indicating on a board in the ground floor the location of the fire, and simultaneously automatically giving the fire brigade station telegraphic information of fire.

All fire appliances will be regularly inspected and tested at short intervals to ensure they are always in working order.

Finally, mention should be made of the rapidity of construction, the building being completed in twelve months, the erection of the steel work, amounting to 3,000 tons, occupying less than half this time. The contractors have indeed justified their reputation for carrying out work in a rapid and efficient manner.

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A REINFORCED CONCRETE CEMENT STORAGE BUILDING AT NEW JERSEY, U.S.A.

In the following pages we present an article describing a reinforced concrete building in the United States, the method adopted being that of casting the members separately on the site, and erecting them after sufficient time has been allowed for setting.

We would draw attention to the fact that the costs given are American, and would probably differ somewhat in this country.—ED.

CRANE HOISTING COLUMN INTO VERTICAL POSITION.

THE method of constructing mill or storage buildings out of concrete by casting the members separately and erecting them after they have become sufficiently hard or "set" to handle, has been followed by a Portland Cement Company at New Jersey, U.S.A., for something over a year; during this time that company built two kiln buildings and one clinker storage building. This article describes a Cement Storage Building.

We show a general plan and end elevation of the building, which is designed to hold 350,000 barrels of cement; the overall dimensions being 144 ft. by 360 ft. by 30 ft. high.

On account of the pressure of cement when stored in bulk, the side walls were made in place by the usual method, but the columns, girders, and roof slabs were cast about half a mile away, and brought to the site by rail for erection.

The roof, which has an area of over 50,000 sq. ft., is made of concrete slabs 12 ft. by 6 ft. by 4 in. thick. These slabs are supported by concrete girders, which in turn are carried by the columns. There is also an additional row of girders and columns on one side of the building for the purpose of carrying the conveyors, etc., which deliver cement into the building.

Altogether 141 columns, 187 girders, and 720 roof slabs were brought on to the site.

The Forms for Moulding Members.—In preparing to cast the members a half-yard Ransome Concrete Mixer was set up at a place convenient for getting stone, and then a spur track run to it which was connected to the main line of railroad by a switch. On each side of the spur track, which was on practically level ground, beds were levelled off and 4 in. of cinder put on them; then the cinder was wet down and rammed, and concrete 4 in. to 5 in. thick placed on it. The surface was levelled off

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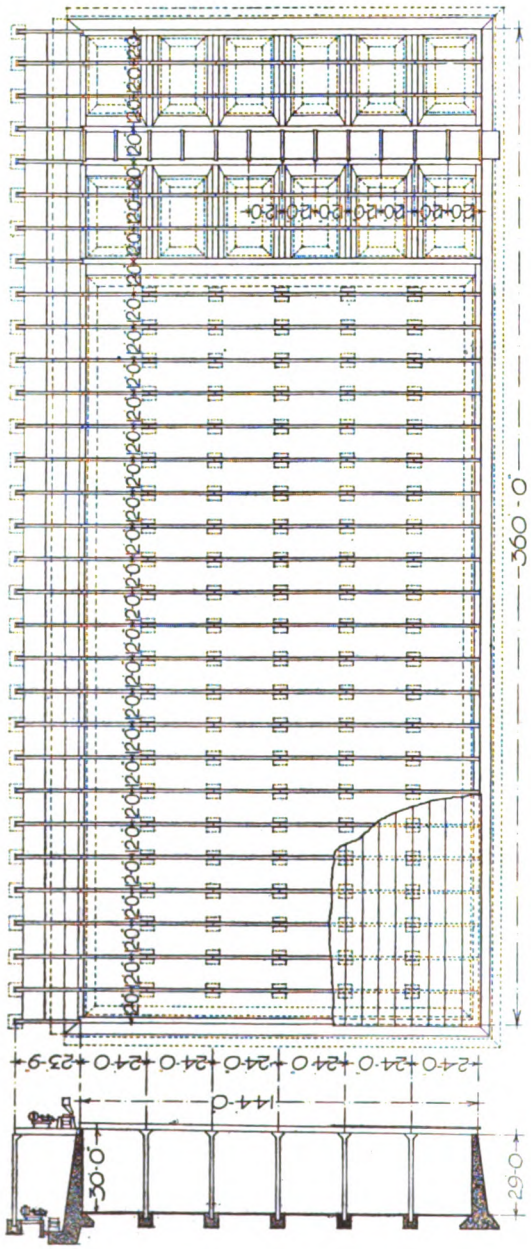
and smoothed with a trowel. These casting floors or beds were made of various sizes to suit the members which were to be made on them, the usual size being 10 ft. by 50 ft. It was estimated that these casting floors would be much cheaper than floors made of timber. This was borne out by the cost records, which show the beds to cost about 2d. per sq. ft.



Reinforced Concrete Cement Storage Building, New Jersey, U.S.A.
(General plan and end elevation.)

The column forms were made of 2 in. timber planed one side and two edges. They were made 20 in. deep, 2 in. deeper than the columns, so that in setting up on top of a column previously cast, it would clamp 2 in. on the lower column, which would facilitate setting the forms. The yokes used were 2 in. by 6 in. as shown, with a spreader at the top and a $\frac{3}{4}$-in. bolt through just above the form. Altogether seven column forms were made, and with these were cast 141 columns. The forms were in good condition at the end of the work and could easily have been used for as many more columns.

The girder forms are built just like the column forms, and used in the same manner. Five girder forms only were made, and with these 187 girders were cast. Frequently girders were cast with no forms of timber, and sometimes one-half of a form only was used, the previously cast girders being used as forms.

The roof-slab forms are somewhat different; these are made 8 in. deep, with the upper half identical with the lower half, except that it is offset 4 in. endways. The upper 4 in. is the form proper, while the lower 4 in. is used to clamp on the slab below. The offset is made to enable the slabs to be lifted after they are cast. The bevel strips are put on to give the edges of the slab a taper, so as to have a place

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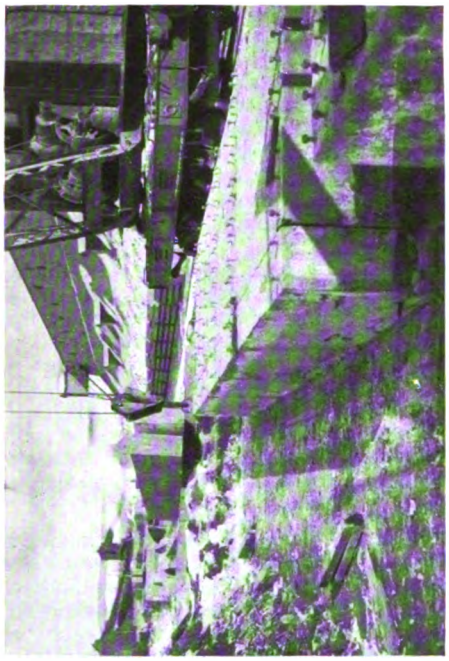
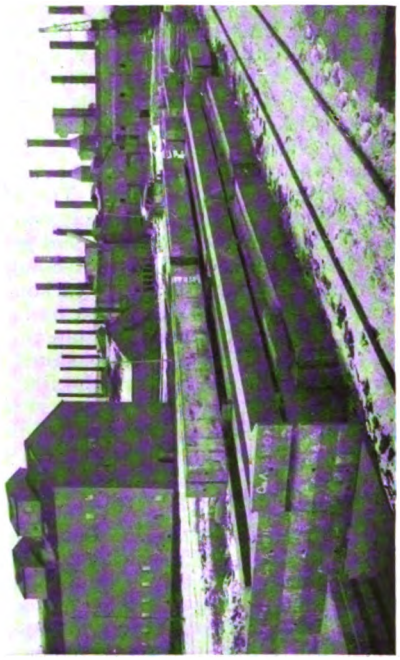
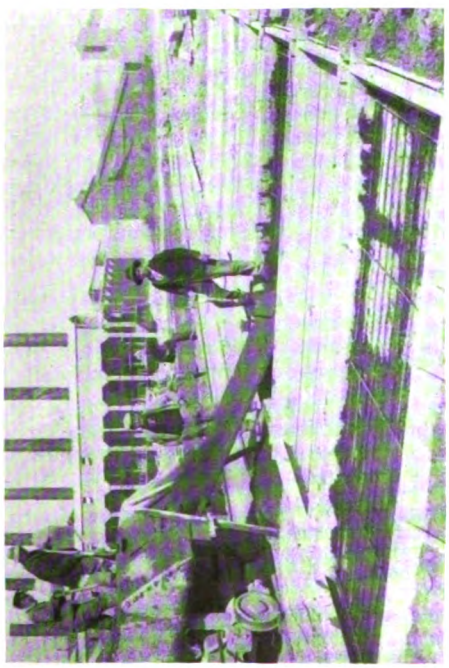


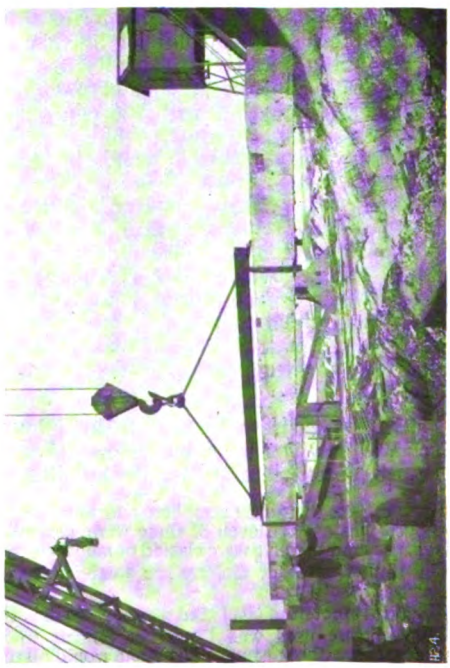
A girder drying bed. These girders are placed on the outside of the building, and the hooks shown are for fastening the necessary machinery.



A number of girder columns. These columns were cast 3 and 4 deep.



Showing the method and reinforcing of the roof slabs. The steel rods are within ¾-in. of bottom of slab.



One of the columns being loaded by the crane.

REINFORCED CONCRETE CEMENT STORAGE BUILDING, NEW JERSEY, U.S.A.

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for caulking to make a weather-proof joint. Twenty-eight of these forms were made.

Dimensions of Members (Columns, Girders, and Roof Slabs).—The columns are 32 ft. long and 18 in. sq., with two knee braces extending 18 in. at the top. The reinforcing consists of four $\frac{7}{8}$-in. high carbon twisted steel rods with hoops of $\frac{1}{4}$-in. steel spaced 9 in. centres. The foundations for each column were 5 ft. cubes made in place with the socket 20 in. sq. The depth of these sockets was left low, and after all foundations were in the bottoms were grouted up to the proper height. By this method was made the slope on the roof, which has a pitch of 1 ft. in 150 ft.; all columns were made the same length. The top of the foundation was reinforced to prevent breaking out. Two pieces of pipe were cast in the top of columns for bolting on the plates, which hold the column and girder together.

The girder is of straight rectangular form 24 ft. by 2 ft. 2 in. by 1 ft. thick, reinforced by four $\frac{7}{8}$-in. high carbon twisted steel rods with hoops, and two small rounds in the top. Pipes were cast in the ends for fastening to the columns, and 2 in. by 2 ft. wood blocks set in at intervals for the purpose of connecting electric wires.

The roof slabs, as before stated, are 6 ft. by 12 ft. by 4 in. thick, reinforced with twelve $\frac{3}{8}$-in. sq. rods in the line of its supports. There were also used five $\frac{3}{8}$-in. sq. rods cross-ways for reinforcement in handling. The edges are bevelled $\frac{3}{8}$-in., making an opening of $\frac{3}{4}$-in. at the top when the roof slabs are in place. In regard to the roof slabs, it may be mentioned that the inside of the concrete forms were given a heavy coat of ordinary whitewash before a slab was cast. This method was used throughout, and found to be very satisfactory.

Placing Members in Position.—In assembling the building, the column is first set in the socket, which has 1 in. clearance all round. It is plumbed, and then wooden wedges are driven in to hold it. A grout of one part of cement and three parts of sand is then poured in; as soon as this sets sufficiently the wedges are removed and the space filled with more grout. The tops of the columns and the bottoms of the girders where they rest on the columns are soaked with water for some hours before the girders are set in place. This is done by tying burlap (a heavy cloth) on these parts and soaking it. Then a mortar of one part of cement to three parts of sand is put on the top of the columns, and the girders set in place, which squeezes out the mortar making a perfect bed for itself. The roof slabs are then placed on the girders with a mortar joint the same as between column and girder.

It was found, that with the concrete mixture, which was made very wet, that it is not necessary to waterproof the slabs in any way, as they show only a little dampness for a short while, and the pores soon seal up, which leaves only the joint between the roof slabs to be taken care of. This is done by first caulking the taper crack with oakum for about 2 in. deep; the edges are then cleaned and painted, and the remaining 2 in. filled with a composition made of one-third coal tar and two-thirds cement, boiled together and applied while hot. This has proved to be entirely satisfactory, and is a very inexpensive filling.

In addition to the mortar joint between the column and girder, a $\frac{1}{2}$-in. steel plate is bolted on, which connects the two girders to the columns. This was believed to be unnecessary, but was put on as an additional precaution. The roof slabs are not fastened in any way, and dependence is made upon the mortar joint and their weight entirely.

Cost. — Accurate costs were kept by the building owners of the cast members, which will be given later, but before doing this, some general data in regard to making the 1,048 pieces necessary for the building will be presented.

The work on these cast members was all done in two months. The average number of men employed was 23. Eleven of these were classed as carpenters and foremen, whose average rate was 1s. per hour; twelve were classed as labourers, whose average rate was 7½d. per hour.

The timber used for making the 1,048 pieces was 7,000 board feet, which at £5 8s. per 1,000 ft. makes a total of £37 8s.

The total amount of steel used was 201,400 lbs., the total cost of which was £817 12s.

The mixture used was 1 part of cement to 6 parts of stone, using the run (average) of crusher stone without sand. The stone would all pass a ¾ in. screen.

In the following costs the stone is figured at 2s. 8d. per cubic yard, while the cement is figured at 4s. per barrel.

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Approximate cost of each column on casting floor :—

	£	s.	d.
Cost of steel	1	14	4*
Cost of material for concrete	1	2	0
Carpenter labour	0	17	3
Labour, making and placing concrete and reinforcing	0	7	10

NOTE —5 dollars are taken as equal to one pound, English money, and a cent. as equal to one halfpenny.

The cost per cu. yd. concrete without steel is 14s. 8d.

If these columns had been made of yellow pine at £7 per 1,000 ft. and of the same dimensions, the timber alone would cost £6 14s. 6d., as compared with £3 17s. 2d. for complete concrete column.

Approximate cost of each girder on casting floor :—

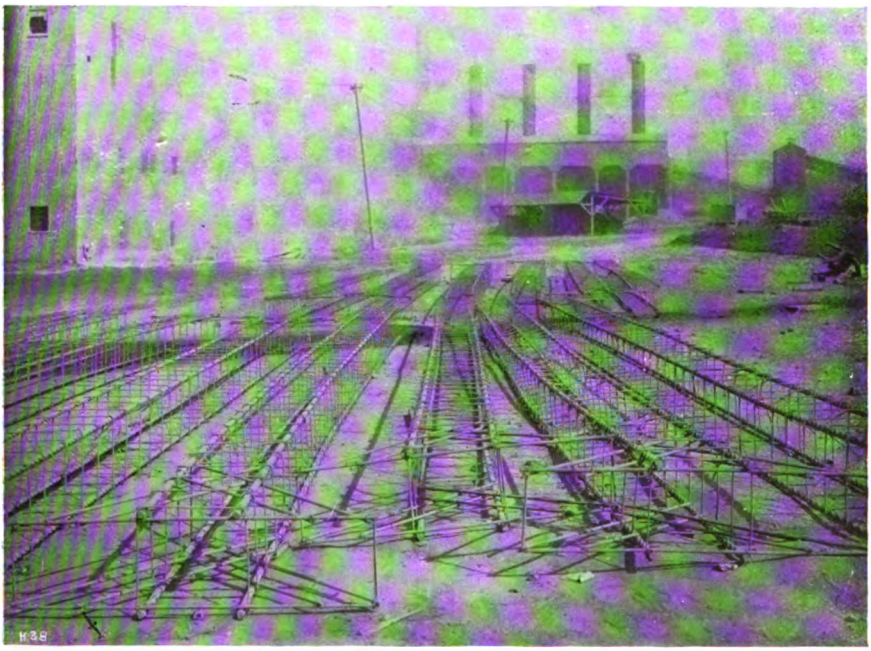
	£	s.	d.		£	s.	d.
Steel	1	2	2	Carpenter labour	0	9	1
Concrete material	0	14	1	Labour, mixing & placing, etc.	0	5	5

The cost per cu. yd. concrete without steel is 16s. 10d.

If it were made of yellow pine at £7 per 1,000 ft. and of the same dimensions, the cost of timber alone would be £4 7s. 6d., as compared with £2 10s. 8d. for concrete girder complete.

Cost of each roof slab complete on casting floor :—

	s.	d.		s.	d.
Steel	6	10	Labour, mixing and placing concrete, whitewashing, smoothing tops, etc.	1	6
Concrete material	7	6			
Carpenter labour	1	8			



REINFORCED CONCRETE CEMENT STORAGE BUILDING, NEW JERSEY, U.S.A.
Reinforcement for columns made up and fastened together ready to be set in the forms.
These are made by Italian labour, and cost 3/6 each.

There are 72 sq. ft. in each slab, therefore the cost per sq. ft. is £1 4s. 3d. per 100 sq. ft.

Compare this with corrugated iron as a roofing material. Good practice on roofs is to use 18 gauge corrugated iron :—

	£	s.	d.		£	s.	d.
Weight per sq. with usual lap is 292 lbs. (for the iron alone)	1	15	10	Paint for 3 coats	0	2	7
				Labour, painting	0	1	6
				Labour, putting on	0	11	1

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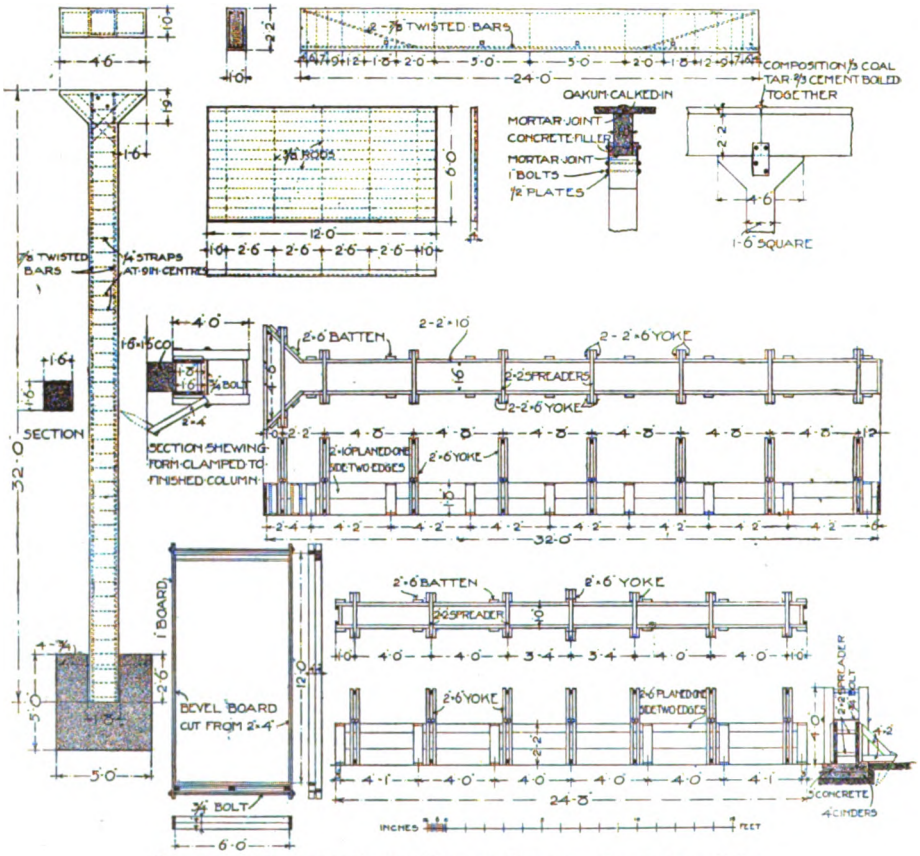
The actual figures for laying the concrete slabs cannot be given, but a bid was presented from a responsible party to erect the entire roof, columns, and girders for £386 8s.

It was done cheaper by day labour. If this latter figure is assumed, however, as the cost and the erection of the slabs allowed to be one-half of it (as there are 518 squares in the building), then :—

	£	s.	d.		£	s.	d.
Cost of erection per sq. is ...	0	7	6	Cost of slabs per sq. is ...	1	4	3

That is, the cost of the corrugated iron is more than 50 per cent. above the cost of the concrete roof slabs.

One of the roof slabs was tested to destruction ; it failed at 7,700 lbs. centre load, with 12 ft. span. This gives an ample factor of safety for a roof.



REINFORCED CONCRETE CEMENT STORAGE BUILDING, NEW JERSEY, U.S.A.
Details of reinforcement and wooden forms for columns and beams.

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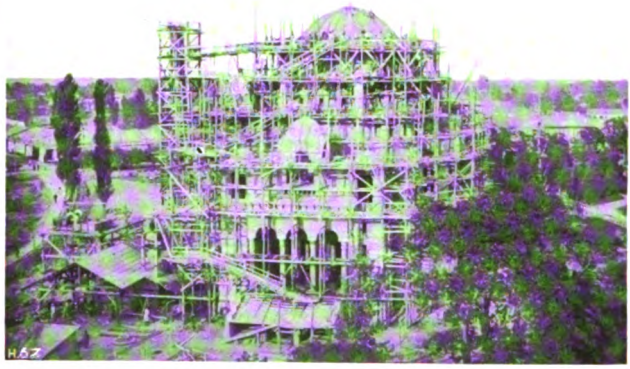
Reinforced Concrete Cathedral in Poti, Russia.



We are reproducing in the following pages some photographs and plans of a reinforced concrete cathedral which has recently been erected in Poti, Russia, and which is beautifully situated in the mountainous regions of the Caucasus. We consider this one of the most interesting examples of this form of construction we have yet described. We are indebted for our photographs, drawings, and particulars to our contemporary, "Le Beton Armé," of Paris.—ED.

SEVERAL propositions for the erection of this cathedral were put forward, the original idea being to construct it in masonry and bricks, but these materials are costly in Russia, and, moreover, difficulties arose regarding the foundations, owing to the peculiarity of the soil, which was very unstable, and also the difficult position which had been selected for the site of the cathedral.

It was finally decided that reinforced concrete would best answer the purpose, and be the most practical form of construction, owing to its great resistance, and its cheapness as compared with other forms of construction; also it was found that the erection could be carried on more expeditiously than if masonry had been employed.

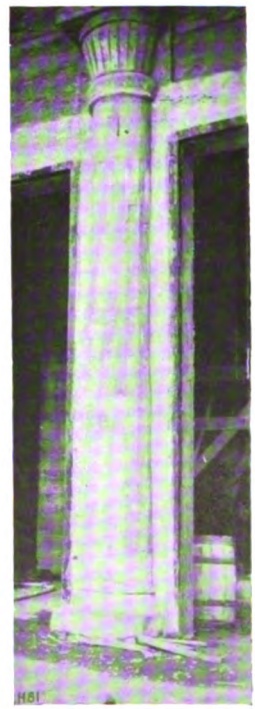
The style of architecture adopted was that of the Byzantine period. The architectural plans were prepared by Professor Marfeld, whilst the reinforced concrete work was carried out on the Hennebique system, all the calculations and plans being in accordance with this well-known system of construction.

The walls represented as solid walls on the ground floor plan were carried out like double walls, or partitions. They comprised an interior partition of 8 cm., and an external partition of 10 cm., with an air space of 18 cm. between the two, being in all 36 cm.

For a good architectural rendering it was necessary to build the large pillars very massively, and so it was possible to make allowance for the ventilation and heating channels in these pillars.

The cupolas are formed from a structure of 10 cm., reinforced by branches of 25 cm. in height, between which an isolating material was laid before laying on the large iron covering.

The concreting of the foundations was started on July



REINFORCED CONCRETE CATHEDRAL IN POTI, RUSSIA.
Pillar at Main Entrance.

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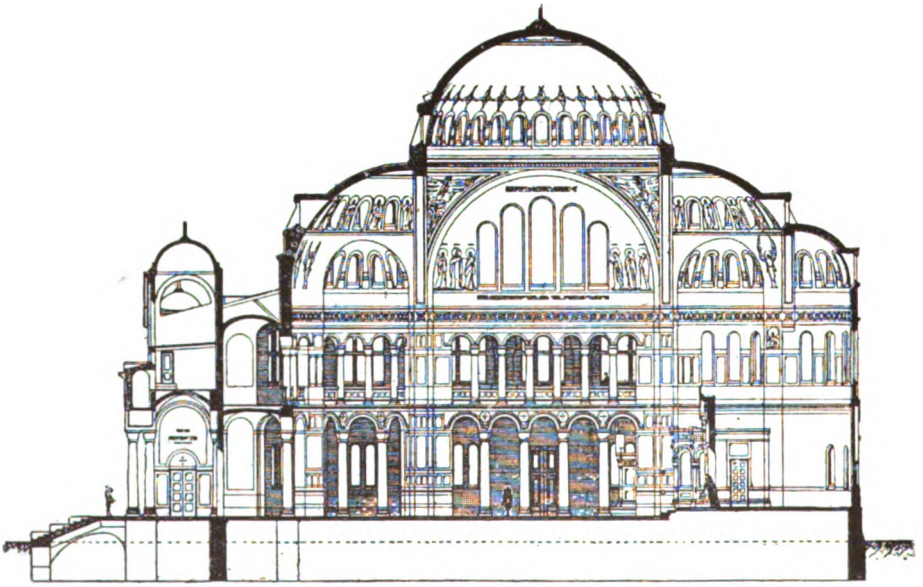
West Façade.



Reinforced Concrete Cathedral in Poti, Russia.
Longitudinal Section.

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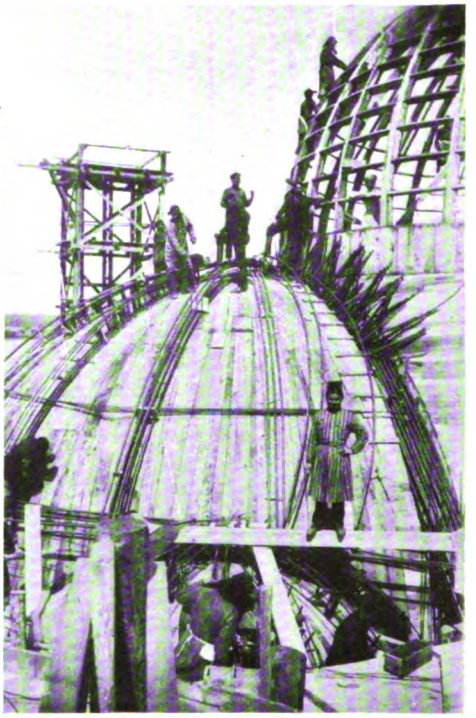
Reinforcing the large and small half cupolas.

Reinforcing the large half cupolas.



Centering for the belfry.

Centering for the arches (2nd floor)

REINFORCED CONCRETE CATHEDRAL IN POTI, RUSSIA.

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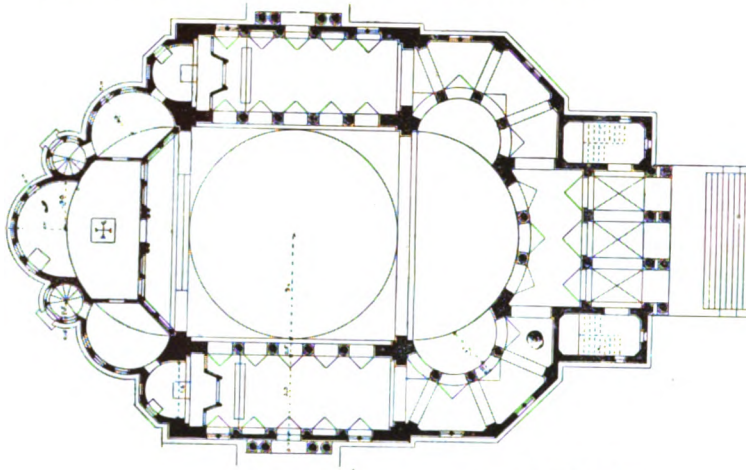
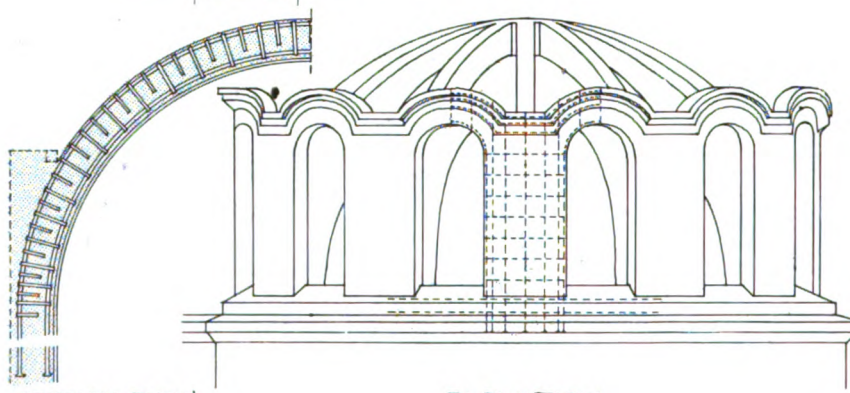


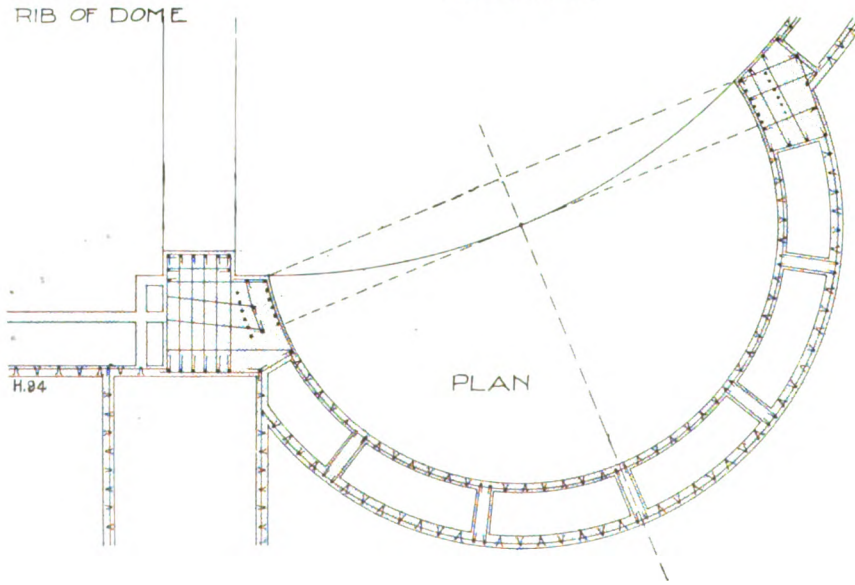
REINFORCED CONCRETE CATHEDRAL IN POTI, RUSSIA.

Ground floor plan, and plan, elevation, and section of dome.



SECTION THRO' RIB OF DOME

ELEVATION



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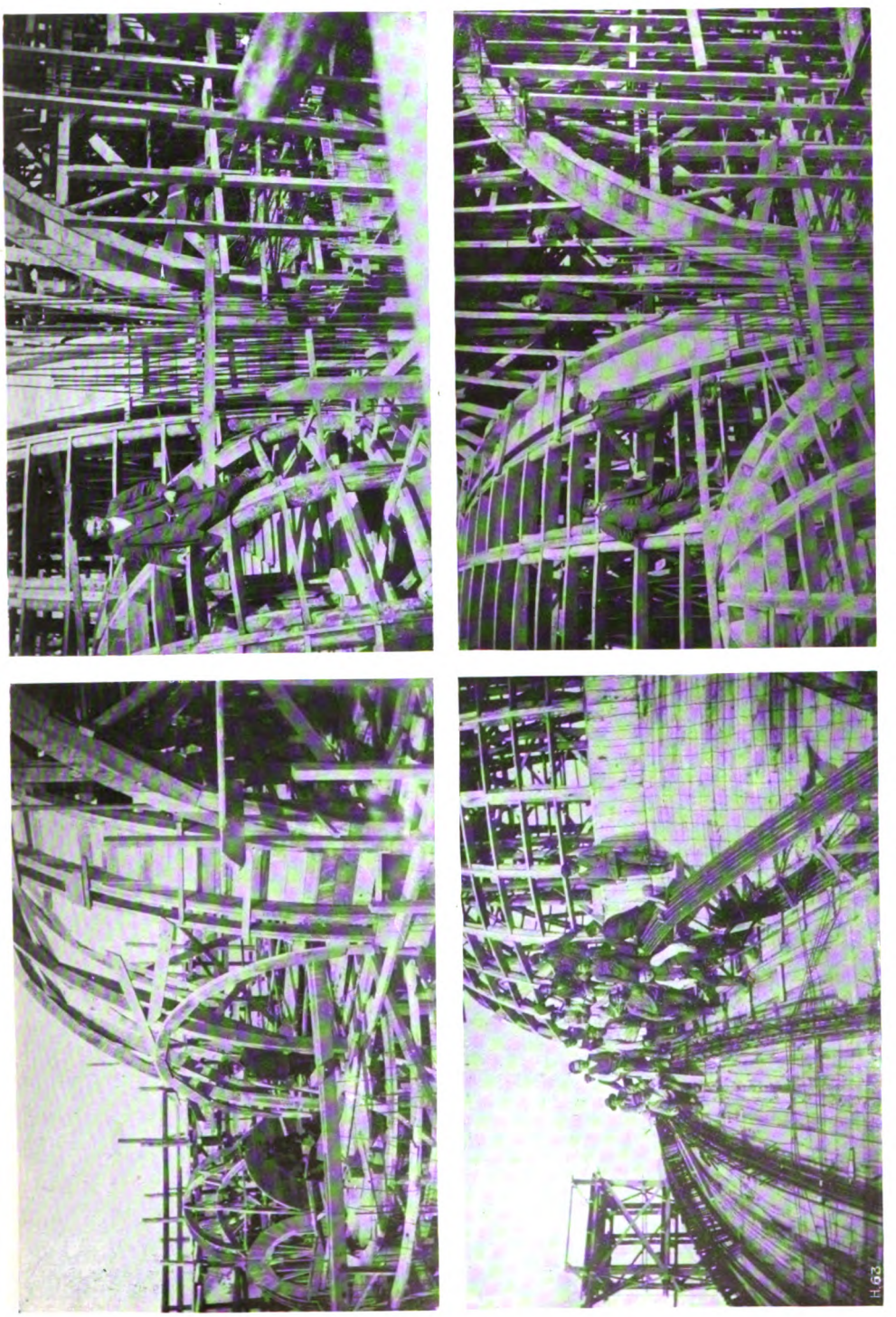

REINFORCED CONCRETE CATHEDRAL IN POTI, RUSSIA.
Views showing placing of reinforcement and centering of cupolas and vaulting.

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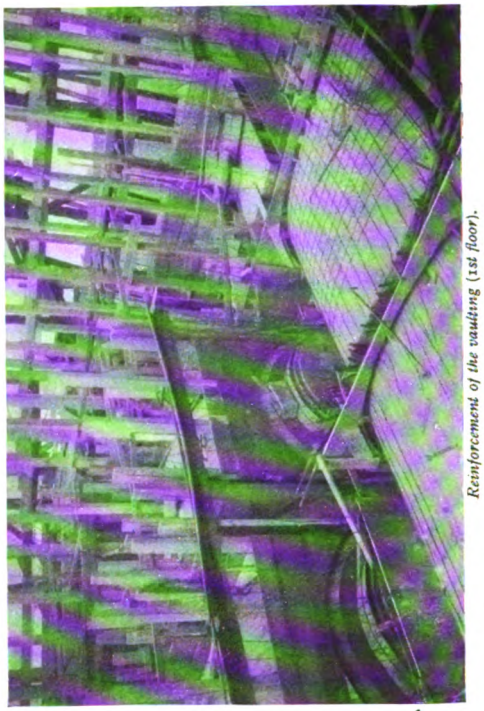
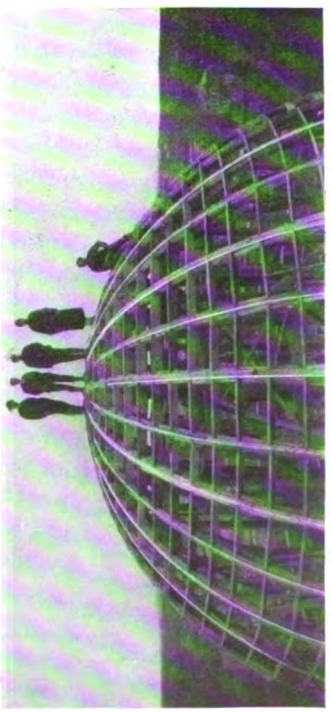
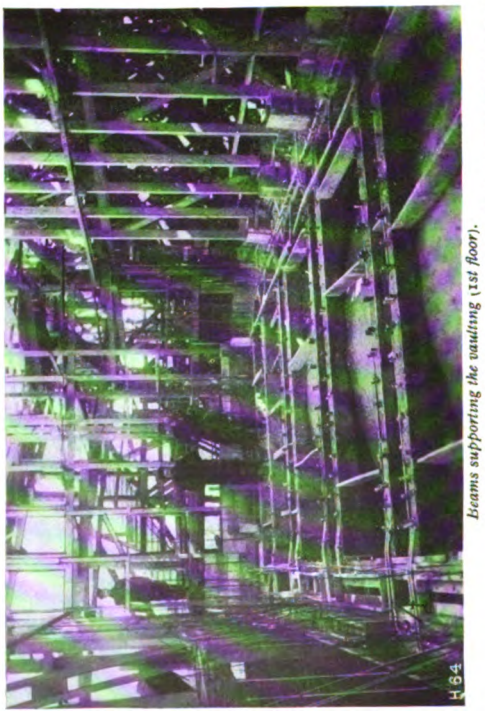
Reinforcement of the great cupola.



Reinforcement of the vaulting (1st floor).



Centering of the great cupola.



Beams supporting the vaulting (1st floor).

REINFORCED CONCRETE CATHEDRAL IN POTI, RUSSIA.

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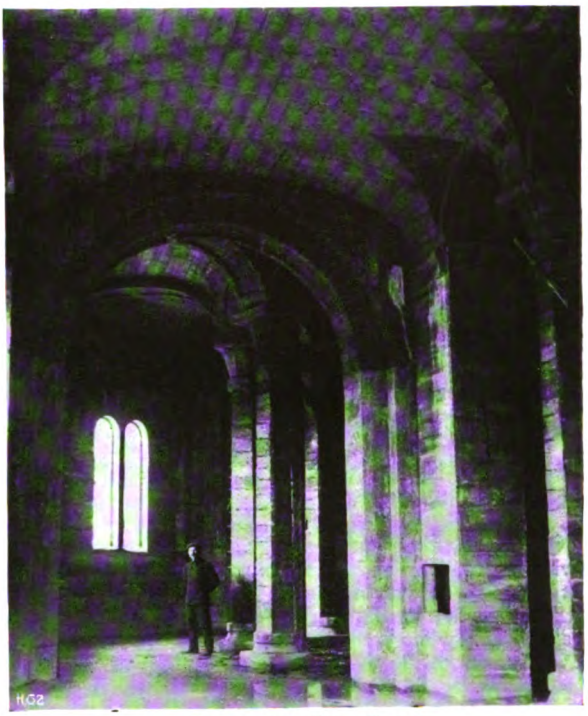
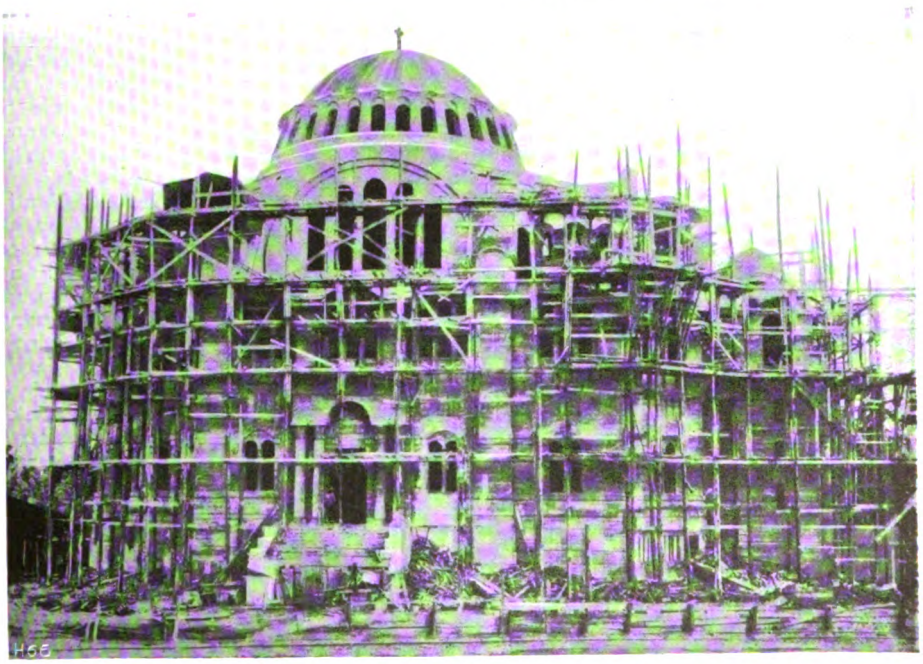
6th, 1906, and the concreting of the large cupola, including the cross, was finished on May 22nd, 1907.

The building was passed by the controlling authorities, after having been tested according to the regulation tests, which showed but an insignificant deflection of ½ mm. for the principal arches, which have a span of 12.30 m., and a deflection of only 2 mm. on the total height of 29.10 m. from the springing to the topmost point of the grand cupola.

It might be added that this important structure was carried on at a period when Russia was passing through very troublous times, and, moreover, the ignorance of the workmen out there rendered the execution particularly difficult.



VAULTING ON FIRST FLOOR.



REINFORCED CONCRETE CATHEDRAL IN POTI, RUSSIA.
Principal elevation during construction.

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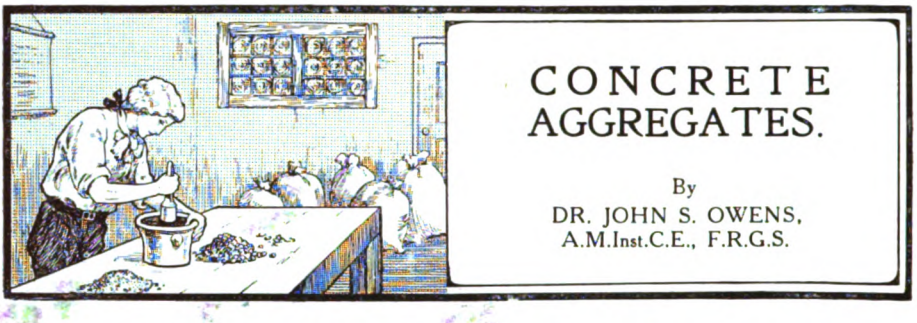

CONCRETE AGGREGATES.

By
DR. JOHN S. OWENS,
A.M.Inst.C.E., F.R.G.S.

We are pleased to see that greater attention is now being paid to the question of concrete aggregates. It has been for so long a matter of custom to give the very closest attention to the quality of Portland cement, the cleanliness of the water, and also to a certain extent to take special trouble as to the sand, but there has all too often been neglect as to the quality of the aggregate.

As to what the aggregate should be, the Special Commission on Concrete Aggregates, formed by the British Fire Prevention Committee, have made some valuable suggestions and drafted some specifications, which we published in our previous issue.

In this instance we are presenting a general commentary on the subject.—ED.

In considering the subject of aggregates for use in making concrete we are dealing with one which is of great importance both to the engineer and to the general public. It is also, unfortunately, a subject which seldom receives the close attention it deserves when specifications for concrete works are being prepared. This is the more remarkable when we remember the numbers of such works which are being constructed every day, both in this country and abroad.

However carefully we may specify the tests which the cement to be used must satisfy, or the number of turns which must be given to mix the concrete, there yet remains the aggregate itself; by far the largest part of the concrete, relative to the selection of which we have not yet adopted any standardised rules which are worthy of the name. All our care in the selection of a cement, or in other matters important enough in their way, may be nullified unless we thoroughly and intelligently consider the question of aggregates also. Concrete, or reinforced concrete structures, may collapse, or may not fulfil the sanguine expectations of their designers, and the cause, diligently sought for, perhaps, in the design, or some fault in the cement, may lie in a lack of due appreciation of the probable effect of some peculiarity in the aggregate used.

In dealing with this subject I cannot do better than adopt the classification decided on by the Special Commission on Concrete Aggregates appointed by the British Fire Prevention Committee, the Interim Report of which appeared in our last issue. Aggregates were divided by the Commission into Natural and Artificial. It is matter for regret that some attempt has not been made before to standardise specifications for aggregates, and give to concrete users concise and definite data as to the qualities of the various materials, regarded from this point of view. It is to be hoped that the Commission will carry out, or cause to be carried out the necessary research work to enable an authoritative statement to be made on all doubtful points. That the question of aggregates should have been taken up at last by such an authoritative body as the Special Commission is a matter of congratulation, and the tests proposed by that body should certainly have the support of the public authorities concerned.

In preparing this article I have therefore not attempted to deal fully with such points, nor to pronounce upon aspects of the matter which are *sub judice;* but, rather, by a somewhat general discussion of the whole matter, to place before the reader the main principles governing the selection and proportioning of aggregates. The following points are dealt with more or less briefly: General properties essential in aggregates; impurities; proportions; and moisture.

It is customary to consider concrete as composed of coarse particles of stone or gravel, and a certain proportion of sand and cement; but, although this describes

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fairly accurately the concrete usually met with, it will be seen when we consider the effect of lack of uniformity in the sizes of the particles composing the aggregate that the densest and strongest concrete is made from an aggregate which does not fall in with this description; but is really a mass of stones of all sizes from the maximum allowable down to that of sand grains. Such concrete is therefore really a mass of stones cemented together. There is a vast difference between this conception of concrete and that which pictures a certain volume of stone of a fairly uniform size mixed with an appropriate quantity of sand and cement.

Having made this clear it becomes necessary, to conform with the actual conditions usually holding in practice, to consider concrete as being composed of: (*a*) Coarse particles of stone, or other hard material. (*b*) Sand. (*c*) Cement. (*d*) Water. But it should be clearly understood that this division is arbitrary, and that there should be no line of demarkation between (*a*) and (*b*), but rather a gradual shading off of one into the other.

General Properties of Aggregates.

We pass on now to a consideration of the general properties which are essential in all aggregates for use with Portland cement. These may be briefly enumerated as follows:—

The material should be such as will bond well with the cement. This bond depends not only on the nature of the material itself, but also on the shape of the individual particles and the kind of surface possessed by them. A false idea as to the strength of bond between any particular material and cement may be given when such material is very porous, by using it without having previously soaked it with water. This results in absorption by the aggregate of the water which should be available for the cement, and hence improper setting of the latter and a bad bond.

The effect of shape may be seen when we remember that of all shapes the sphere exposes the least surface compared with its volume; and, as it is to the surface the cement adheres, clearly a large superficial area in the particles is an advantage, within certain limits. We should, therefore, prefer angular to rounded or water-worn aggregates, when other factors bearing on our choice are equal. Slaty aggregates, or those in which the particles are very thin and flat, are, however, an exception to this rule, and make poor concrete, as it is very difficult to get such particles to lie well in the mass; they are disposed to "bridge" and form cavities.

As will be brought out in more detail when considering the subject of voids, lack of uniformity in the size of the particles composing an aggregate is an advantage, and permits us to make a denser concrete. It also enables us to effect an economy in cement, as it is found that the more uniform in size the particles are the greater the voids to be filled up between them with sand and cement.

Again, no substance should be present in an aggregate which might have a deleterious effect upon the setting properties of the cement, and so upon the strength of the concrete. As examples of such substances the following may be mentioned: Clay or mud, if present in any quantity, such as is often found mixed with pit ballast, and with that obtained from the beds of muddy streams. Free lime, sometimes found in blast furnace slag; old mortar, dust and soot, as is usually to be found mixed with broken bricks from old buildings; sulphur, sometimes in injurious quantities in coke breeze, clinker, etc.

Much has been said as to the question of size of particle allowable in aggregates. This depends altogether upon the nature of the work. I refer now to the maximum size, not the minimum, which is fixed by other considerations. There are certain types of work, such as heavy foundations, in which large masses of rock may be embedded and may properly be considered as forming part of the aggregate. No evil results from this if certain precautions are observed. Such "plums," as they are sometimes called, should be perfectly clean, and well separated from each other, and from the surfaces of the work; great care should also be taken to assure their thorough saturation with water if of a porous nature, or they may exert an injurious influence on the work owing to absorption of water from the surrounding cement, and the formation of a bad bond with the surface of the stone. On the other hand, for the construction of, say, slabs of reinforced concrete only a few inches in thickness, we must rigidly limit the size of the particles to a maximum of $\frac{3}{4}$-in. gauge.

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Impurities.

The impurities usually met with in natural aggregates are: Clay or marl; peat; loam; vegetable matter and decayed stones.

Much has been written relative to the effect of clay upon concrete, and many diametrically opposite opinions have been advanced. There is not space here to go fully into the matter; but it may be stated that certain points are fairly well agreed upon by engineers. Clay, when it exists as a coating to the particles of the aggregate, is undoubtedly injurious, as it prevents a proper adhesion between the cement and the surfaces of the stones. When, however, it exists to a small extent throughout the mass of the aggregate in the form of separate particles, clay appears to be harmless in many kinds of concrete work. Some authorities have held that as much as 10 per cent. may be permitted in this form. The question is one which calls for further investigation.

There is no doubt as to the injurious nature of vegetable matter, peat, loam, and rotten stone. Such impurities greatly reduce the strength of the concrete, and aggregates giving evidence of the presence of any of these in appreciable quantities should be washed before use. The presence of decayed stone may indeed necessitate the entire discarding of the material.

Clay may be detected, in an aggregate, by the well known method of rubbing the finer parts between the hands; if clean, the sand should not adhere to or discolour the hands. Or, again, a small quantity may be stirred in water in a glass, or shaken up with water in a test tube, when the presence of clay will at once be shown by the characteristic turbidity of the water. Vegetable matter, being of lower sp. gr. than the sand will separate out and settle in a layer on the top of the latter in the glass or tube.

Turning to the impurities contained in artificial aggregates. We find that sulphur figures very prominently; it is met with in burnt ballast, coke breeze, clinker, and blast furnace slag. It is probable, however, that its importance has been somewhat over-estimated, especially as to its effect in causing rust on steel reinforcements, as it is hard to see what evil effect a small percentage of sulphur can have upon the steel in the presence of the alkaline cement. The permissible amount of sulphur in an aggregate has yet to be fixed, but until it has been shown by careful observation and research that a small percentage is not injurious it is safer to avoid aggregates containing sulphur in any appreciable quantity.

A very common impurity in burnt ballast arises from imperfect burning. I refer to lumps of partially or insufficiently burnt clay; care should be taken that all the clay be burnt to a pale brick colour. When under-burnt the lumps are of a darker red, and can easily be distinguished by their colour.

We may find all sorts of impurities mixed with these artificial aggregates, such as old mortar, dust, sooty bricks, rags, and other rubbish; but these do not call for special attention here, except to say that sooty pieces of broken brick are very likely to cause stains to appear on the surface of the concrete.

Voids in Aggregates.

The subject of voids is of great importance, and calls for close consideration, as only by a due appreciation of the laws which govern the percentage of voids can we understand how to obtain dense non-porous concrete. As is now well known, it is of the utmost importance in relation to the preservation of steel embedded in concrete that the surrounding mass should not be spongy or porous.

The highest percentage of voids is obtained in an aggregate, the particles of which are of one uniform size; this may be over 60 per cent. Theoretically, a mass composed of uniformly-sized spheres arranged in the most compact manner possible contains 26 per cent. of voids. It has, however, been shown by Fuller that it is impossible to pour or tamp spheres into a measure in such a way as to have less than 44 per cent. of voids. Now if we provide particles of such dimensions, and in such proportions that the voids between the largest are nearly filled by the next largest, and the remaining voids by smaller grains still, we can thus reduce the percentage to a minimum. Hence, as opposed to an aggregate of uniform grain which contains the highest proportion of voids, such an aggregate of graded sizes will have the lowest possible proportion of voids between its particles, and will therefore give the densest and strongest concrete.

To determine the percentage of voids in any aggregate, water is often used; the material to be tested is placed in a vessel of known capacity, water poured in, and the amount required to fill the interstices measured. If the material is originally dry,

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and the water fills all the voids, clearly this method will give an accurate result; and in effect it is accurate for coarse, non-porous, materials, such as broken stone. With finer aggregates, however, it has been found very difficult to drive out all the air contained in the voids by pouring water on to the material in this way, and an error of 8 or 10 per cent. may easily be made. If, instead, a measured volume of dry sand be poured very slowly into a glass vessel containing water, it sinks to the bottom free from air bubbles, and the volume of displaced water may be measured and deducted from the volume of the sand, the difference being that of the voids. When testing materials by either of these methods it will invalidate the result if they are very porous, as the stone will absorb the water into itself, thereby giving a larger value for the voids than represents the true state of affairs. This may be avoided by saturating the material with water before testing.

A more accurate method, when the aggregate is composed of stones of the same nature, such as all flint, or all granite, is as follows: Suppose, for simplicity, that we have a measure containing exactly 1 cub. ft. of the sand or stone which we desire to test. We now dry the aggregate by heating in an oven to over boiling point of water (212 F.) until it ceases to lose weight, and note the weight at that moment, deducting that of the measure. Let w be this weight, and W that of a cubic foot of the solid rock, of which the aggregate is composed—this may be got from tables—then the ratio of voids to solid will be equal to $\frac{W-w}{W}$.

The percentage of voids will be equal to $\frac{W-w}{W} \times 100$, or $\left(1-\frac{w}{W}\right) \times 100$

This is, however, applicable only when the aggregate is composed of one kind of stone, the density of which we know; for gravels made up of particles of different kinds of stone we must have recourse to the water test, which fortunately is sufficiently accurate for such.

To get non-porous concrete all these voids must be filled, and no increase of strength is given by filling voids with cement and sand which might be filled with small stones and cement; in fact, the strength has been shown to be sometimes increased by the substitution of stone for some of the sand. It must be remembered that concrete is to be regarded as composed of stones or other hard material cemented together; and, as in building, thick joints of mortar between the stones or bricks in a wall are rightly considered an evidence of bad workmanship, so thick joints of cement between the stones of the aggregate are bad. They are also wasteful, since cement is usually more costly than stone.

As the proportion of voids depends somewhat upon the amount of ramming or compacting which the aggregate gets, it is assumed here that they are simply poured or shovelled into a vessel, and not rammed, when measuring the percentage of voids. It is better to slightly overestimate this than to underestimate.

It should be noted that the proportion which the volume of the voids bears to that of the aggregate does not depend upon the size of the particles, provided they are uniform the actual size does not matter.

That this is so is brought out in the following table of some of M. Feret's results. It gives the percentage of voids in aggregates of variously sized particles, both rounded and angular.

Size of Particles.		Percentage of Voids.	
% passed by a ring of a diam. in m/m.	% refused by a ring of a diam. in m m.	Rounded Pebbles.	Broken Stone.
90	60	41·4	52·1
60	40	40·0	53·4
40	20	38·8	51·7
20	10	41·7	52·1

It will be seen from this that the voids are greater with angular than rounded materials. Hence, concrete, having an aggregate of broken stone, calls for more cement than that made from rounded particles of gravel or shingle and sand. The angular pieces do not bed together as closely as the more rounded. It is usually agreed, however, that the larger and rougher surface of the broken stone

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gives a better bond to the cement, and so a stronger concrete than is given by water-worn gravel. A point worth remembering in this connection is that concrete structures when reinforced with steel are not designed to withstand tension; and there is not much, if any, advantage in favour of the broken stone over gravel in compression. It is not easy to compare them on a fair basis, because if the same volume of cement, sand, and stone or gravel be used in making the concrete for the test blocks, if the proportions are correct for the broken stone they will probably be wrong for the gravel, since its voids will be less. The gravel concrete will, therefore, have rather more than enough mortar to fill its voids, and this will probably influence the result.

Proportions.

Turning now to the important subject of proportioning the various ingredients of concrete, as affected by the nature of the aggregate, this is also a part of concrete making which receives far too little care, as not only the strength of concrete structures, but also their durability, depends more than is often realised upon the amount of care and intelligence which has been devoted to fixing proportions. It is essential that the right amount of stone, sand, and cement should be used if we are to get the best results, and the right amount is not a mere matter of opinion, but can be arrived at scientifically and accurately by fairly simple means.

It has been shown conclusively that if there is not enough mortar to fill the voids between the coarse particles of stone, a serious diminution of strength results. Not only is this so, but the concrete, being porous, permits leakage of water through it, which is an unsatisfactory state of affairs in the case of reservoirs and tanks, and in the case of sea works is liable to bring about their premature destruction by the chemical action of the sea-water.

The correct amount of cement to be used in any particular case where we desire the best result is therefore that which will fill completely the interstices of the aggregate, when the concrete is in position. In the case of broken stone of, say, 1½ to 2-in. gauge, which has been screened, the voids are usually about 45 to 50 per cent., hence we must provide this proportion of sand and cement mortar to fill them. Gravel may have, say, 30 to 40 per cent. of voids; we must, therefore, use a similar percentage of mortar. The actual spaces to be filled are somewhat in excess of the amount shown by the water test or weighing, if the gravel or stone and sand have their voids estimated separately, and the final percentage in the mixture of stone and sand calculated from these figures, owing to particles of sand getting between the stones, and keeping them further apart than they would be in the absence of sand. It is, therefore, better to finally measure the voids after the mixture of stone and sand has been made. It is also well to measure them without ramming the aggregate, as we shall then get a slightly higher figure, which helps to compensate for irregularities in the materials, and keeps us on the safe side.

If we provide much more cement than suffices to fill the interstices it will weaken the concrete in all cases except when such aggregates as coke breeze are used, the strength of which is inferior to that of the cement.

Sand contains usually 40 to 50 per cent. of voids, the actual proportion depending on the degree of uniformity in size of the grain. Supposing then that we have stone containing 50 per cent. of voids, and we supply sufficient sand with a similar percentage to fill these, the resulting mass will have something over 25 per cent. of voids to be filled with cement. Now, cement when mixed with water reduces very much in volume, and it is the mixture of cement and water with which we have to deal now in filling the final voids. It has been found that it takes somewhat over 100 lb. of cement to make 1 cub. ft. of paste; but the exact amount varies with the brand of cement.

It is now a simple matter to provide 100 lb. of cement to each cubic foot of voids in, say, a cubic yard of our aggregate. If we wish to be more accurate still, when the quantities involved are very large, we may determine experimentally the exact weight of cement of the kind to be used which is required to make one cubic foot of paste with water.

Of course, it is not essential to provide the proportions indicated above for all kinds of work, it will depend greatly upon what the concrete is to be used for. It is, however, different in the case of reinforced work; for here we may not permit any porosity or air spaces in the concrete surrounding the steel which can be

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avoided. There appears to be a strong probability that when the embedded steel has been found to rust it is due to the absence of sufficient care in proportioning the concrete, or in ramming it into place.

I refrain from giving here definite figures for the proportions for various aggregates, as I desire to indicate the necessity of dealing with the matter on its merits in each particular case.

To recapitulate briefly the central principles: We should choose an aggregate composed of various sizes from the maximum allowable to that of sand grains. I refer now to the aggregate as a whole, and not as separated into stone and sand. We must then, to get the best result, use enough cement to fill the voids in this aggregate. We may do all that is possible by properly grading the sizes of the particles to reduce the voids, but it comes to this in the end, that we have to provide cement enough to fill them.

The following example of proportioning will illustrate my meaning: Let us assume that we have to use broken stone as part of our aggregate, and we find an experimental determination of the voids gives us 40 per cent. by volume. In this case we are using sand with the stone, we, therefore, if there is any choice, select sand with as irregularly sized grain as possible, and for each yard of stone we allow a little over 10·8 cub. ft., since 1 yd. cube of stone contains $\frac{27 \times 40}{100}$ cub. ft. of voids. Now, if the sand had also 40 per cent. of voids, the resulting mixture will have 16 per cent., and require $\frac{27 \times 16}{100}$ or 4·32 cub. ft. of cement paste, which is equivalent to approximately 432 lb. of dry cement. Our proportions would therefore be:—

Broken Stone	27 cub. ft.
Sand	11 cub. ft.
Cement	432 lb.

It is better to weigh the cement if possible, as its volume dry depends upon how the measure has been filled, and is an uncertain quantity.

These proportions represent what would often be called a strength of about 1 in 7. This is an expression which, while giving the proportion of cement to aggregate with only a poor approach to accuracy, conveys practically no information as to the strength of the concrete. I have seen concrete made from gravel which had been screened to remove the sand for building purposes, and the "strength" of which was about the same as above; but it could hardly be properly called concrete, since it was simply a mass of pebbles cemented together at their points of contact, most of the voids being empty. Many a house is now run up in the suburbs of London where the builder finds it very economical to use the sand screened from his ballast for mortar, and the nice clean pebbles left go to form the concrete foundations. It is no wonder such houses are damp, resting, as they are, on what is practically a sponge. However this may be, it is time we should drop the use of expressions such as 1 in 7 to describe the proportions of concrete; they contain a subtle and dangerous suggestion, not always recognised as a fallacy, that the chief factor determining the strength of concrete is the ratio of cement to aggregate.

Moisture in Aggregates.

A certain proportion of water is always present in aggregates, and it serves a useful purpose, since a damp aggregate can be mixed with cement more easily than a dry one. Each particle when damp picks up a coating of the dry cement when it comes in contact with it. It is important, therefore, to see that the materials of our aggregate are damped before we mix them with the cement; if quite dry there is a tendency for the finer particles of sand and cement to work to the bottom of the mass when mixing. It is curious to note that damp sand is lighter than dry sand, volume for volume, probably because of a separating film of water between the grains in the damp state. This applies also to fine gravel or broken stone. As sand is proportioned by measurement, this results in a slight variation in the actual amount measured, depending on the percentage of moisture. Sand under ordinary circumstances, when damp, will contain 3 or 4 per cent. of water by weight, which may be increased to 18 or 20 per cent. after exposure to rain.

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Selection of Aggregate.

There is not space to go fully into this, it is a question which depends upon the nature of the work and the kind of material which is available. It is naturally more economical to use what can be obtained in the locality where the work is situated, if suitable, than to bring materials from a distance.

The nature of the work will determine whether we must use a heavy, tough, hard material for our aggregate, as when we wish to construct works exposed to the sea; or a light, fireproof material, as when we wish to build the walls and floors of houses.

To endeavour to enumerate all the special properties which may be called for in individual cases would be tedious, and serve no useful purpose here. I will not, therefore, refer further to this, except to say that the choice of a material depends entirely upon the circumstances of each case.

In concluding I would emphasise the necessity which exists for further research work bearing on all the properties of the materials used for aggregates which may exert an influence for good or evil upon the strength of our concrete, and reinforced concrete structures.

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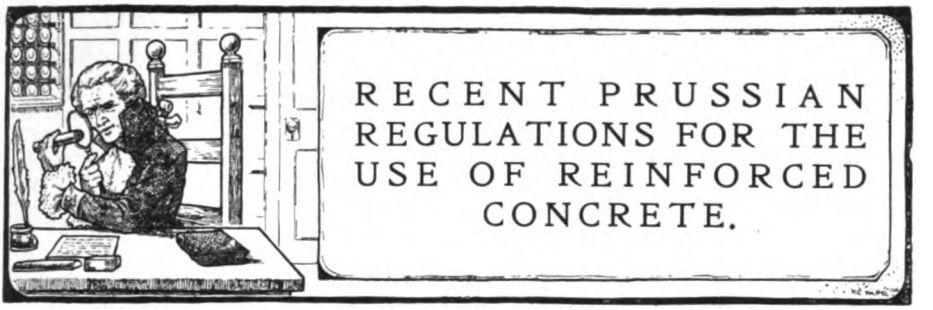

The regulations and recommendations for the use of reinforced concrete in buildings, issued by the Prussian Ministry of Public Works, in 1904, have been superseded by a later official circular, dated 24 May, 1907. The principal clauses in the new regulations are summarised below by Mr. C. F. Marsh from a translation by Mr. C. H. Desch, in a form for comparison with the rules of other countries, tabulated in Mr. C. F. Marsh's article in "Concrete," in July last.—ED.

THE PRINCIPAL ALTERATIONS.

Cement is to be measured by weight, and weight of bags taken at 125½ lb., the weight of barrels being 374 lb.

More explicit directions given as to removal of falsework, etc.

Side casings of beams to be removed in not less than 8 days. That for bottoms of beams in not less than 21 days. For large spans and sections the time may be extended in certain cases up to 6 weeks.

More explicit directions given as to test loading, etc.

Span of beams to be free opening and one support.

Slabs supported on all sides with reinforcing bars crossing one another, when length a is less than 1½ breadth b, under evenly distributed load, to be calculated according to the formula $M = \frac{pb^2}{12}$

Continuity of continuous beams or decking not to be assumed over more than 3 spans.

Resistance of concrete in tension to be neglected except that, in parts exposed to weather, moisture, corrosive gases, or other injurious influences, it must be shown that the tensile stresses are insufficient to produce cracks in the concrete, the permissible stress being ⅔ of the tensile strength. In absence of special tests the tensile strength is to be assumed as not more than 1-10th the compressive strength.

Working resistance of concrete in beams to be assumed as ⅛th the ultimate.

Shearing resistance of concrete to be 64 lb. per sq. in. or 1-5th ultimate.

Adhesive resistance to be same as shearing.

Working tensile resistance of the steel is altered from 17,060 to 14,220 lb. per sq. in.

As far as possible the reinforcements are to be such that displacement relative to the concrete is prevented.

Thickness of slabs of T-beams in no case to be less than 3·15 in.

The calculations have been extended to include doubly reinforced rectangular and T-beams.

Tables have been added giving values of the depth to the neutral axis and stresses in the concrete and steel for various percentages of reinforcement for singly reinforced pieces.

Tables are also given for the effective depth, depth to neutral axis, and area of reinforcement for various working stresses in the concrete and steel for singly reinforced pieces.

The question of diagonal tension has received fuller treatment, and a method is given for calculating sizes of bars for the resistance of shear

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Cement.

Must be Portland cement, fulfilling the conditions of the Prussian specification. Certificates as to quality to contain statements as to constancy of volume, setting time, fineness of grinding, and tensile and compressive strengths. The constancy of volume and setting time must be controlled by the contractor's own tests.

To be delivered in original packages.

Sand and Gravel or Stone.

Must be of suitable quality, and must not contain pieces so large as not to enter between the reinforcing rods

Concrete.

The compressive strength of cubes after 28 days to be determined before commencing work, and stated in the description. (See "General Regulations.")

The cement to be measured by weight (1 sack = 57 kg., 126 lb ; 1 barrel = 170 kg., 374 lb.). Aggregate may be weighed, or measured in vessels so constructed as to hold the required weight.

Erection.

The concrete to be mixed exactly in the specified proportions. When measuring vessels are used, they are always to be filled in exactly the same way.

The concrete to be used immediately after mixing and before setting has begun. It is not to remain unused longer than one hour in warm and dry weather, or more than two hours in cold and wet weather. To be protected before use from sun, wind or heavy rain, and to be turned over just before use.

The ramming must be continued without a break.

The concrete to be put in place in layers not more than 15 cm. (6 in.) thick, and rammed to an extent proportioned to the wetness of the mass.

For ramming, properly shaped stamps of appropriate weight must be used. Reinforcing rods to be thoroughly cleaned from dirt, grease and loose rust. Care to be taken that all reinforcing rods are properly spaced and tightly packed in concrete. When the reinforcement is arranged in several layers, each layer to be packed separately in concrete.

A thickness of at least 2 cm. (0·8 in.) of concrete to be left beneath all reinforcing rods in beams, and at least 1 cm. (0·4 in.) in floors.

Further layers of concrete should as far as possible be put in place while the earlier layers are still fresh; in all cases the surface of the earlier layer must be roughened.

Hardened surfaces to be roughened, swept, wetted, and covered with a thin cement grout immediately before adding a fresh layer.

In the construction of columns, the concrete must be introduced from one side, remaining open for inspection as long as possible.

In the construction of walls and columns, the upper storey not to be commenced until the lower has hardened sufficiently. Three days' notice to be given to the authority before commencing the upper storey.

During frost, only such work to be done as can be protected from the effects of frost by suitable precautions.

After prolonged frosts, work not to be recommenced without official permission. Frozen materials must not be used. Until sufficiently hardened, concrete to be protected from frost, premature drying, shaking and overloading.

Time book to be kept. Days of frost to be entered with record of temperature.

Falsework.

To possess sufficient resistance to bending and shaking during ramming, and to be arranged so as to be removable without danger to the necessary supports remaining in place.

At least three days' notice of the completion of falsework and commencement of concreting in any storey to be given to the authority.

All shaking to be avoided during removal.

Striking Centres.

The time between moulding and removal of casings and falsework to depend on the weather, and on the span and weight of the structural members. The casings for columns, centering for floors, and side casings for beams may be removed not less than eight days, that for the bottoms of beams not less than twenty-one days, after moulding. For large spans and sections, the time may be extended in certain cases up to six weeks.

Special care to be taken in removal if concrete is finished shortly before commencement of a frost.

If frost occurs during the setting of concrete, the above periods are to be increased by the time of duration of the frost.

Testing.

Compression cubes to be provided, 30 cm. (12 in.) side, to be dated and sealed. Tests may be made by the authority in any approved manner. Tests may be made on the works by means of an officially controlled press.

Portions of building in positions determined by building authority are to be exposed if desired, so that the mode of construction can be seen. Special tests may be made to determine hardness and strength.

Should doubt exist as to hardness and correct mixing, test-pieces may be cut out of the finished building.

If loading tests are considered necessary, they are to be carried out under the instructions of the building authority. Loading tests are not to be made in less than forty-five days after setting, and are to be strictly limited to what is considered necessary by the authority.

When a floor is tested, the load added is not to exceed one-half the weight of the floor and one-and-a-half times the evenly-distributed working load. When the working load is more than 1000 kg. per sq. m. (205 lb. per sq. ft.), this may be diminished down to once the working load.

When a strip in a floor or decking is to be tested, the load is to be evenly distributed in the midst of the floor over a strip of length equal to the span and width one-third of the span, but in any case not less than 1 m. (39 in.) In this case the test load must not exceed the weight of the strip and twice the working load. The weight of floors is to be reckoned as defined below. In testing columns or piers, unequal loading of the building, and loading of the foundations beyond the permissible limit, are to be avoided.

Loading.

Weight of concrete shall be taken as 2,400 kg. per cub. m. (150 lb. per cub. ft.) unless a different weight is definitely determined.

The weight of any covering to floor must be added to dead load.

For parts of structures subjected to considerable vibration or to greatly varying loads, such as floors of public and dancing halls, factories or workshops, the superimposed load to be multiplied by $1\frac{1}{2}$.

For parts subjected to heavy shocks, such as roofs of vaults under passages or courtyards, the super-imposed load to be multiplied by 2.

Bending Moments, &c.

Span for beams to be free opening plus one support.

Span of continuous decking to be distance from centre to centre of supports.

For freely supported decking, the free span plus the thickness of the decking.

Bending moments and reactions to be determined by formulæ for freely supported or continuous beams according to mode of support and distribution of load.

For continuous decking, the bending moment at centre of span is to be taken as four-fifths of that which would exist in a freely-supported panel, unless the moments and reactions can be ascertained.

The above rule holds good for beams, excepting that no end moment is to be taken into account unless special arrangements have been made to fix the ends.

Decking and beams only to be reckoned as continuous if resting on solid supports in one plane, or on reinforced concrete beams.

Continuity not to be assumed over more than three spans.

Allowable Stresses.

$$\frac{E_s}{E_c} = 15$$

unless definitely determined to be different,

Resistance of concrete in tension to be neglected, except that in parts exposed to weather, moisture, corrosive gases or other injurious influences, it must be shown that the tensile stresses are insufficient to produce cracks in the concrete. The permissible stress is then $\frac{1}{5}$ of the

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tensile strength. In the absence of tests as to tensile strength of concrete it is to be reckoned as not more than $\frac{1}{10}$ the compressive strength.

Concrete in beams, $\frac{1}{6}$ ultimate compressive resistance.

Concrete in simple compression, $\frac{1}{10}$ ultimate resistance.

Concrete in shear, 64 lb. per sq. in. or $\frac{1}{5}$ ultimate.

Adhesion of concrete to steel same as in shear.

Steel in tension or compression not to exceed 1,000 kg. per sq. cm. (14,220 lb. per sq. in.)

As far as possible, the reinforcements to be of such form that displacement relative to the concrete is prevented.

Rules for Calculation.

The deformation in a piece subjected to bending directly proportional to distance from neutral axis.

Width of slab acting with T-beam to be not more than $\frac{1}{4}$ span.

Shearing and adhesion stresses to be calculated and special provision made to resist these if necessary.

In columns, the possibility of eccentric loading is to be taken into account.

Beams and floors must not be assumed to be continuous over more than three spans. When the working load is more than 1,000 kg. per sq. m. (205 lb. per sq. ft.), the most unfavourable distribution of load is to be taken into account.

In determining position of reinforcement, the possibility of negative moments is in all cases carefully to be considered.

Calculation for flexure of columns to be made whenever height exceeds 18 times least diameter.

Transverse connections in columns not to be further apart than 30 times diameter of rods. Euler's formula to be used for calculating flexure, a factor of safety of 5 being allowed for the reinforcement.

Slabs supported on all sides, with reinforcing rods crossing one another, when the length a is less than $1\frac{1}{2}$ times the breadth b, under evenly distributed load, to be calculated according to the formula $M = \frac{pb^2}{12}$

The thickness of slabs, and of the flat portion of T beams in no case to be less than 8 cm.

General Regulations.

Special authorisation required for erection of any building or part of a building in reinforced concrete.

Application for permission must be accompanied by drawings, statical calculations and descriptions.

Description must state origin and nature of materials to be used in concrete, the proportions in which they are to be mixed, the proportion of water and the compressive strength to be attained by 30 cm. (12 in.) cubes after 28 days. If required by the authority, tests of compressive strength may be made before commencing work.

Application to be signed by the building owner, the designer, and the contractor charged with the erection. Any change of contractor to be at once notified.

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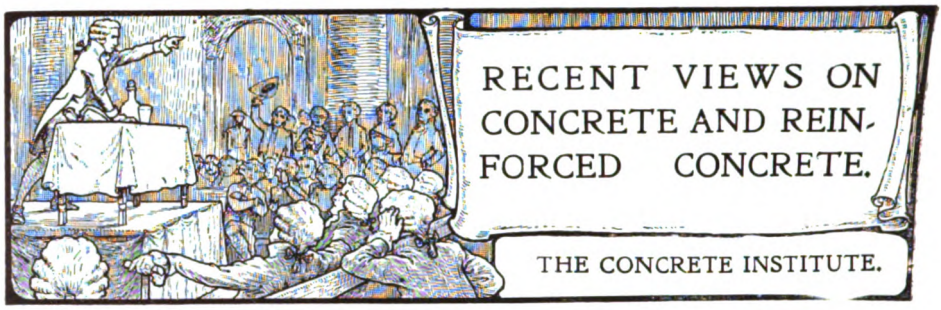

It is our intention to present the Papers and Discussions of the Concrete Institute in a concise form, and in such a manner as to be easily available for reference purposes.

The method we are adopting, of dividing the subjects into sections, is, we believe, a new departure.—ED.

SINCE our previous issue the third meeting of the Concrete Institute has been held. Both the paper and the discussion called for favourable comment, and we are again presenting a summary of some length.

The meeting was again held at the Royal United Service Institution, and the attendance was considerable. The procedure of carrying through the business in a plain, straightforward manner, without superfluous laudation and votes of thanks finds favour, for it allows for the time available for discussion to be occupied to its fullest extent, and, what is more, occupied in a bright manner. The speakers also kept strictly within their "ten minutes" limit, which is a considerable advantage where but two hours are available for paper and discussion combined. The meeting was presided over by Mr. Edwin O. Sachs, F.R.S.Ed., Chairman of the Executive, and the reader of the paper was Mr. Lucien Serraillier.

The formal title of the paper was "Some Commercial Aspects of Reinforced Concrete," and many of those attending expected under this heading particulars as to costs, business organisation, and perhaps even an insight as to how profits can be made, but it was pleasant to observe that the reader of the paper took a very broad view of the title, and, as elsewhere mentioned, dealt mainly with the very important questions of the relations of the specialist contractor to the client, to the client's professional advisers, and to the general contractor of a building, the paper also embracing the problem of preparing specialist designs and estimates on insufficient data and the abuse of entering into contracts without a proper allotment of responsibilities.

The discussion speaks for itself, but the divergencies of view between the members of the technical professions and those of the managers of the industries concerned were somewhat marked, and if a paper and discussion of this description does something towards leading to a better understanding between the professions and industries—as has been so frequently the case at the meetings of the Iron and Steel Institute—a great step forward will have been made in the development of reinforced concrete in this country.

As to the Institute's work, it is generally known that its Parliamentary Committee has been much occupied of late with matters relating to building legislation in London, and that its Science Committee is actively engaged in the solution of various important technical problems.

The first half volume of transactions and notes of the Institute has reached the members, and the part before us gives not only a full verbatim report of the papers and discussions of the first two meetings, but also a *précis* of the more important doings of the Council and Committees of the Institute and communications of note received or issued by them. Thus the volume of notes and transactions may be said to combine both the features aimed at by those societies who publish journals at regular intervals and those who publish their transactions only. This will probably be found to be a very practical manner for dealing with the work of the Institute for the present, for the interest of the general membership in the literature issued will

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thus be likely to be retained. Where institutions publish their transactions only, and this generally only at wide intervals, they all too often are left unopened by the members, who have either attended the meetings reported or read the usual summaries which appear in the public Press. By adding some notes relating to the principal doings of the Institute the members are kept in touch with the doings of their Council and Committees, and the knowledge of there being such notes in the volumes issued will cause many of them to immediately refer to the literature as it appears.

As mentioned elsewhere, the membership has been gradually increasing, and we would only add that particulars of the Institute can be obtained from the Hon. General Secretary (Mr. A. E. Collins, M.Inst.C.E.) at the offices of the Institute at No. 1 Waterloo Place, Pall Mall, London, S.W.

THE THIRD MEETING.

SOME COMMERCIAL ASPECTS OF REINFORCED CONCRETE.

PAPER by LUCIEN SERRAILLIER.

The Chairman, Mr. Edwin O. Sachs, F.R.S.Ed. (Chairman of the Executive), opened the proceedings by announcing tha the roll of members and subscribers now totalled over 500.

The Chairman then asked Mr. Serraillier to read his Paper.

MR. LUCIEN SERRAILLIER, Reader of the Paper.

Generally.—The lecturer stated that the relation which subsisted between (*a*) the client or principal (*b*) his technical adviser, and (*c*) the contractor in ordinary civil engineering and architectural construction was more complex in reinforced concrete construction, whilst the recent advent in England of firms which were endeavouring to popularise this particular industry had further intensified the complexity of this relation. The present paper was an attempt to define the duties and responsibilities towards each other of the various parties engaged in this class of construction, to explain the conditions which govern its exploitation, and to determine between (*a*) the principal or engineer and architect, (*b*) the specialist firm which confines itself to this branch of construction, and (*c*) the contractor, an equitable relation which should, as far as possible, conciliate all interests and eliminate those injustices which now unfortunately arose, undoubtedly through ignorance of those peculiar conditions rather than through intention.

The principal, or his technical agent the engineer or architect, hereafter called the client, had two methods at his disposal under which reinforced concrete work could be undertaken: (1) He might design the structure himself, and either confide the work to a contractor under his supervision or else carry it out himself with his own gang of men; (2) he might entrust the design to a specialist firm, and either carry it out himself with his own men, or with his own contractors, or else get the specialist firms to do it themselves or through contractors selected by them.

The first method was the usual practice adopted in general civil engineering and architectural construction, whereas the second method might be said to be peculiar to reinforced concrete, although sometimes adopted for steelwork. The technical and practical difficulties of the reinforced concrete industry were of such a special nature that the client generally preferred to employ a specialist firm, to whom he thus delegated his duties and responsibilities, contenting himself with a secondary control.

Division of the Work.—Reinforced concrete work might be subdivided into—

I. The design.

II. The execution.

III. The reinforcing material employed (as also other materials of construction which do not concern us in this paper).

These were respectively contributed by the designer, the contractor, and the merchant. By designer the lecturer understood the engineer, the architect, or the specialist firm, as the case might be, who was the author of the design. The contractor was the one who executed the work, and was not necessarily distinct from the designer, whilst the merchant might be, and was in some cases, both designer and contractor. The work was carried out from start to finish through the separate agency of these three divisions, or by combinations of them, and it was precisely those combinations which introduced the complications to which he referred at the commencement of the paper.

In ordinary construction, matters were simple enough, because the engineer or architect who was the designer of the work assumed control of its execution, and was responsible for such, although any mistake on his part affected his reputation, but never his pocket. In that case the designer not only controlled the contractor, but indirectly, through the latter, also controlled the merchants who supplied the material; he had the right of rejection, and in virtue of the fact that he held the purse-strings his power was supreme.

In reinforced concrete, matters were not so simple, for where the designer was a specialist firm, it was the engineer or architect who then became the principal or client, and the specialist firm assumed his duties and responsibilities, and certain additional responsibilities into the bargain.

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The Intrusion of the Specialist Firm.—The point which concerned them in the paper was the case where the assistance of a specialist firm was called in either by the client direct or through his technical adviser. There were two categories of specialist firms : (A) Those which derived their profits from the exploitation of a patent system of construction ; and (B) those which derived their profits from the exploitation of a patent form of reinforcing material.

The firm which exploited a *patent system of construction* combined divisions I. and II. previously referred to—*i.e.*, the supply of the design and its execution. The execution was generally carried out by contractors specially licensed by the specialist firm, whose work was approved by the latter. On the other hand, the firm which exploited a *patent form of reinforcing material* combined divisions I. and III.—*i.e.*, the supply of the design and of the necessary reinforcing material. In this case the execution was generally tendered upon by non-licensed contractors, with sometimes, however, a certain restriction in their selection. Where a specialist firm executed the work itself, it came within the category of a licensed contractor for that special contract.

The logical method would doubtless be for specialist firms to combine all three divisions, and supply design, execution, and materials, thus doing the whole work throughout themselves. But it was obviously impossible, under present conditions, for any single firm to keep up the enormous organisation which would be necessary to carry out contracts simultaneously in all parts of the country.

Each method of exploitation had its use and advantages, and the selection of method by the client would depend on circumstances and on local conditions. There was room in this country for all methods and systems, and no doubt in time these would settle down into specific grooves, so that certain classes of work would be carried out on certain lines, and some co-relation would be established between the various firms and systems which would apportion the work to the interests of all concerned.

Responsibilities.—It would be conceded as a general principle that responsibility should be confined to duties undertaken. It was illogical, for instance, to fasten responsibility of execution upon a specialist firm which was not afforded the opportunity of control and supervision of work. It was unfair to expect this firm to make good any mistakes in quantity of material which might arise in estimates ; and yet this was continually occurring. The client, when ignorant of the method of construction he was about to adopt, naturally looked to the specialist firm for a guarantee. A refusal to accept this guarantee would frequently lose the work, because the client imagined that the firm had no confidence in its system. The real reason for refusal was that no provision was made for supervision, and, as so much depended upon the actual work upon the site, no specialist firm which valued its reputation would accept such responsibilities, unless it was in a position to supervise. Clearly responsibility in this case should be accepted by the contractor, but he would frequently refuse, under the impression that everything depended upon the system adopted ; naturally, if he could avoid such liability he would do so.

The ordinary responsibilities of a specialist firm should be limited to the design and to the quality of the reinforcing material, when the latter also was supplied. When a full guarantee involving construction was exacted, the firm should stipulate for proper supervision and control over the contractor by one of its staff appointed as resident engineer, with suitable remuneration for such service.

The question of responsibility, therefore, should be clearly defined at the outset of every contract, and those specialist firms which did not carry out contracts themselves should stand together in resisting the imposition of guarantee for work which they could not control, or otherwise any resulting disaster would affect the reputation of all.

In the case of firms which exploited systems of construction, the responsibilities were, of course, more clearly indicated. The firm guaranteed its design and the licensed contractor guaranteed its execution. The reinforcing material being purchased by the contractor, the latter was responsible for it, but had the right of rejection. In this case the specialist firm occupied the place of the technical adviser, and risked its reputation like the latter, but not its pocket, except as regarded the guarantee of design pure and simple.

Data.—The client, the lecturer thought, should remember that the more complete information he supplied to the specialist firm he employed the more expeditiously and intelligently would his plans be prepared. Particulars concerning the loads to be carried, nature of soil and foundations, materials available near site, were essential. Architects should say whether the specified loads included the dead load or not ; the tendency to omit this information often placed reinforced concrete in unfair comparison with ordinary steel joist construction.

The nature of the test load should be specified at the outset. Sufficient attention was not paid to the question of fire protection. The nature of the aggregate, whether sharp or smooth, a specification of the cement and its setting time, the breaking and elastic limits of the steel, whether concrete should be mixed wet or fairly dry, etc., should be stated. The height of the floor above ground when only one floor had to be supplied would materially affect the price, and even the scantlings of available timber for centering, will, if known beforehand, enable the beams to be so designed as to utilise it without waste and thereby effect a saving. So that no details were too insignificant to be despised.

A point on which confusion often arose was the factor of safety. A comparison of competitive designs on a large contract would frequently reveal an extraordinary diversity in the factors of safety when these were reduced to the same denominator.

The client should at the outset clearly indicate whether designs were to be tendered upon by contractors selected by him or by contractors associated with and approved by the specialist firms. This saved time and useless correspondence, and would enable the latter to give detailed information to contractors with whom they were not associated when these were specified by the client, which was not necessary in the case of contractors with whom they worked together. Clients should, in justice to competitors, place them all on the same footing, and any deviation from this rule should be resisted by competing specialist firms, who should co-operate in refusing to submit designs under conditions which did not give all the same chance.

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Preparation of Designs.—When inviting competitive designs the client should not ask for too many details at the outset, but should be content with diagrammatic plans which indicated the system proposed sufficiently clearly to enable him to make a selection. He should remember that plans were generally prepared free of charge by specialist firms, and consideration should be shown by not throwing too much useless work upon them. The present tendency was to require too much detail before the selection of a specialist firm was made, and this was particularly irritating when schemes were only in their initial stage.

It was a regrettable fact, to which attention must unfortunately be called, that designs obtained from one specialist firm were sometimes sent by the client to a competitive firm to see if the latter could improve upon them. A design was the property of the designing firm and should be respected as a privileged communication until the client had acquired it on the terms on which it is submitted. The communication to a rival was a breach of faith which the lecturer suggested should be met by a joint undertaking by specialist firms to refuse work offered under such conditions.

Estimates.—Generally the client was in a tremendous hurry for his plans. Hurry meant mistakes, and for these the specialist firm had to suffer. The modern system of bustle and strenuousness, so much admired in another hemisphere, was peculiarly unsuitable for reinforced concrete, for in this, more than in any other branch of construction, more haste meant less speed. Engineers and architects who took months to mature a plan expected very often full detailed plans by return of post. Specialist firms should resist such demands, and refuse work for which a proper time allowance was not made, rather than risk a disaster which may affect all concerned in the industry.

Differentiation of Work.—There was a present tendency to lump all classes of work together, and to invite tenders on the whole contract, even in cases where the reinforced concrete portion is relatively insignificant as compared with the remainder of the contract.

It could not be too strongly insisted upon that reinforced concrete was a separate subject altogether, and that the portion of a contract which concerned it should be scheduled apart from the other portions of the same contract, and separate tenders invited upon it.

In the case where the reinforced concrete portion was the most considerable part of an important contract, the other portions might form sub-contracts. But it was essential to differentiate the reinforced concrete from the rest, so that the estimates from specialist firms might be compared together on their merits without being affected by other portions of the contract. A satisfactory tender would frequently be spoilt by the addition of excessive sums for other portions of the work with which the contractor was not familiar and for which he provided too large a sum to cover himself against possible loss. This occurred specially in cases where prices were sent in hurriedly and the specialist firm or the other contractor had no time to obtain sub-estimates from contractors versed in that class of work.

Payments.—It was desirable that specialist firms (B) which supplied reinforcing material should receive payment for this and for their designs, if these were charged for, direct from the client, and not from the contractor as at present. This would avoid the frequent unjust detention of moneys for materials supplied to the contractor by the withholding of the necessary certificate of payment when the contractor had failed to satisfy the engineer or architect.

Cheapest Not Always the Best.—This was perhaps a trite saying, but in no case was it more applicable than in the case of reinforced concrete. The tendency in this country was to go for the lowest tender without reference to the status of the contracting firm or the quality of the design. The cheap tender which cut out the offers of good firms might frequently come from an unsatisfactory contractor or from one who was ignorant of the difficulties he had to encounter, or who desired to get the work at any cost as an advertisement. The carrying out of the work under these conditions became a source of expense and worry to the client, and he was likely to regret his selection.

Local Government Board Loans.—The London Building Act now in course of revision would, it was hoped, be so amended as to give an impetus to construction in the Metropolis, which had hitherto been restricted by regulations which were drafted when reinforced concrete was an unknown method of construction; but, unfortunately, difficulties were still experienced with the Local Government Board in respect to satisfactory loan periods for reinforced concrete structures, which it would not sanction on the same terms of repayment as other forms of construction such as brick, timber, etc.

The Chairman then called upon Mr. Wentworth Shields, M.Inst.C.E., to open the Discussion.

MR. WENTWORTH SHIELDS, M.Inst.C.E.

Specialist Firms.—Mr. Shields stated that reinforced concrete had brought into being specialists of two kinds, the specialist who designed and the merchant specialist, both of whom had done good work.

He considered the specialist had to work under a disadvantage, owing to the great difficulties that arose sometimes from what might be called dual control, a sort of divided control of the architect or engineer and the specialist, but he thought there might have been cases when the difficulty had been the other way round.

Mr. Shields considered that in spite of the good work done by the specialist in this country he was bound to disappear—at all events, the designer specialist—but he deserved great credit for having preached reinforced concrete in season and out of season to a very apathetic public, and had done a lot to forward the use of this most useful material. Things were very much in the same position now as they were half a century ago, when the use of wrought iron and steel girders was first invented. Before that time arch and suspension bridges were common, but when steel girders first came in, the bridge over the Menai Straits was the first large bridge ever built. People were extremely suspicious of wrought iron girders. They seemed to think it was not quite right that those steel plates should be built up to carry heavy loads, but gradually, as confidence was acquired, the extended use of girders may be said to have been spread about by a number of girder-designing specialists.

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As time went on, however, and others got more or less familiar with the theory and practice of girder designing, the specialist died out. The specialist became the architect, and with or without the assistance of a trained draughtsman he designed his own girders; and it was not unlikely that the same thing would happen in reinforced concrete. The time would come when the architect or engineer would make his own designs.

Patents.—It might be argued that the fact that a great many of the designs being in the hands of patentees would prevent this, and the patentees will naturally prefer to make their own designs. The speaker thought the time was close when the fact of having a patent would not be of much value to the designer. Some of the patents had already expired, and the validity of others was being contested, and the time would soon come when the engineer or architect could make his designs without fear of infringing any patent.

Failures.—Referring to the fact that the Local Government Board were apparently prejudiced against reinforced concrete, as they were evidently fearful of failures, Mr. Shields agreed with the author of the paper as to the importance of full details being furnished, and quoted the author's words that "These failures can be traced to bad design or workmanship, to the use of improper materials, to the premature removal of the centering, or to the placing of an excessive test-load before the structure has attained its full strength."

That sounded an alarming statement, but the fact was that the Concrete Institute wanted to investigate these failures, and to lay down such rules for reinforced concrete construction as should practically assure a builder being able to avoid these various causes of failure. Provided such rules were followed a life of 30 years or more could then be guaranteed to a reinforced concrete structure, and the Local Government Board and other municipal and governing authorities would have to fall in, and the full value and usefulness of this type of construction would be everywhere recognised.

MR. A. H. ALBAN SCOTT, M.S.A.

Specialist Firms.—Mr. Scott stated his concurrence with the previous speaker that the concrete specialist would be no more in a few years. It seemed to him entirely wrong in principle that persons who called themselves concrete specialists should do anything else but design the structure. A firm who had a patent material to put on the market or sell could not possibly under any circumstances hold the absolutely unbiassed position they should hold. In certain cases tenders were not invited, and if the specialist had a free hand to do what he liked and got his fees or royalties in proportion to the amount of the material he was using he would be tempted to use far more material than he would if he had no interest in the material.

Tenders.—The proper way was for the whole of the plans to be prepared in the ordinary form to scale of the whole of the work to be reinforced, every part of the structure to be calculated out, every beam having its amount of steel. The quantities were taken out from the drawings, and tenders were invited from any respectable firm of contractors. The lowest or most favourable tenderer was then invited to state what system he could adopt; the specialist firm is then approached. "So and So are to be the builders; we want you to check the calculations, and you will be paid your fees by the builder." Special charges should be put in the bill of quantities: 10 per cent., or whatever might be decided upon.

The Position of the Architect.—If the architect was thus responsible the specialist would get his fees or royalties without any trouble. He would have no chance of supervision, but every opportunity would be taken of consulting him during the course of the work. That would practically put the architect in the position he should occupy.

Referring to the author's statement that a logical method would be for specialist firms to supply design, execution, and materials, Mr. Scott thought that illogical, as a contractor, if a specialist firm, would be made responsible for any fault in design, and the contractor was not commonly responsible for the design, though there was generally a special clause in the contract making him responsible for the materials and workmanship.

MR. E. FIANDER ETCHELLS, F.Phys.Soc., A.M.I.Mech.E.

Failures.—Mr. Etchells stated that if the building authority were to plead for the enactment of an "imprisonment on failure" clause, he thought that there would be a great outcry that such a clause was new and had never been in the law before, and yet, in the oldest code of laws in the world—laws older than the Decalogue—in the Code of Hammurabi, King of Babylon, more than 4,000 years ago, he had read:—

> "If a builder has built a house for a man, and his work is not strong, and if the house he has built falls in and kills the householder, that builder shall be slain." (Laughter.)
>
> "If the child of the householder be killed, the child of that builder shall be slain."
>
> "If the slave of the householder be killed, he shall give slave for slave to the householder."
>
> "If goods have been destroyed, he shall replace all that has been destroyed; and because the house that he built was not made strong, and it has fallen in, he shall restore the fallen house out of his own personal property."
>
> "If a builder has built a house for a man, and his work is not done properly, and a wall shifts, then that builder shall make that wall good with his own silver."

Doubtless this law tended to ensure good construction.

But to-day, more than ever before, the speaker considered that the man who cut things fine and took most risks would get most orders. The contractor who thought to-day of strength

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alone, not counting the cost, would probably end up in the Bankruptcy Court. We all knew how often an order had been missed because some person less scrupulous or more daring had cut down his thicknesses and cut out some of the reinforcements and thus got the coveted order.

Unrestricted competition and "each man his own Concrete Institute" does not make for sound construction and fair prices.

Rules for Reinforced Concrete Construction.—The speaker said he would most strongly urge that the Institute should take up the suggestion given in the paper as to whether the Regulations of the R.I.B.A. Reinforced Concrete Committee should not be adopted by this Institute with the necessary simplifications and amendments. If a report could be got with a backing and support that would obtain national acceptance it would do much to restrain uneven competition, although it might perhaps require legislation to prevent unfair and dangerous competition. If the Institute could confirm or supplement the R.I.B.A. Regulations they would have a chart enabling the convoy of contractors to steer and sail evenly between the Scylla of Bankruptcy and the Charybdis of Disaster.

There was another advantage in that it would reduce the cost of the preliminary drawings submitted with tenders, for it should be sufficient to examine the general lines of the design if all the designs are based on the stress of the R.I.B.A. Report as amended, and, further, the general acceptance of such a Report, with the necessary amendments, would do much to reduce that "extraordinary diversity of safety factors" referred to by the author.

Scamped Work.—Referring to the dangers of hustling in the preparation of drawings for reinforced concrete work spoken of by the author of the paper, Mr. Etchells added that the danger was very much greater in the case of the actual execution of such work on the site.

MR. G. C. WORKMAN.

Responsibility.—Mr. Workman's opinion was that it was quite fair that the specialist designer should be responsible for the design.

Concerning the data, the specialists were suffering very much from the want of data when asked to supply a design. Very often they were not given the data at all, and were left to guess this. Of course they might guess 1 cwt. or 2 cwt., and naturally the views of various designers differed.

Another thing was that they were not given the bearing capacity of the ground. It was absolutely necessary to have proper data. One firm may guess one thing and one something much higher, with the result that there must be great difference in the prices.

Rules for Reinforced Concrete.—The most serious point in the difference is caused by the fact that all did not work on the same stress, it would be only fair that all should work on the rules of the Committee which have been adopted by the Royal Institute of British Architects. At present this is not the case in competition.

The factor of safety was also a vital question. A factor of safety of 5 had been asked for in certain cases, but 3½ was sufficient. Five was very high, but some architects asked for even higher than that. It simply meant a waste of material.

Preparation of Designs.—Mr. Serraillier said, "Far too many details are required from specialists." There was absolutely no doubt about it, but he could understand the architect's points of view. There was such a diversity of systems and methods of placing bars in a beam that the architect naturally required full particulars of each individual case.

Referring to Mr. Serraillier's words regarding the supplying of general plans without details, Mr. Workman said he had no doubt it was a good idea, but did not think architects would agree. More time should, however, be allowed the specialist for the preparation of designs and estimates, as when mistakes are made the specialist naturally suffered.

Failures.—Referring to failures and the effect upon the engineer, Mr. Workman stated that special rules ought to be recognised in an official manner. The rules in the report of the R.I.B.A. Committee on Reinforced Concrete should be adopted, and some steps ought to be taken to try and impress on the authorities the necessity of getting those rules, or similar ones, once and for all recognised.

Loans.—Mr. Workman said that Mr. Coignet had stated there were reinforced concrete buildings in Paris which had been up for 30 years, and were doing very well.

MR. J. MUNRO.

Specialist Firms.—Mr. Munro stated he was in complete accord with most of the paper. Speaking of the logical method being for the specialist firms to combine all three divisions, he hoped the day would come when the people who supply patent bars will do the work themselves as well as the design.

Responsibility.—With regard to responsibility, he held this should be absolutely borne by the specialists, whether they design or carry out, because the architect in these days of stress and bustle had not got much time to indulge in responsibility or accepting a divided responsibility. Of course, in years to come, he expected the architect will have reinforced design at his finger ends, but that was not generally the case at present.

With regard to the quality of the work, he thought that the specialists ought to make good all defects, and ought to be responsible for quantities as well. If an architect gave work to design and carry out, it ought to be undertaken in the same spirit as a builder, and there should not be too divided responsibility.

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With regard to data, he agreed with Mr. Workman in his emphasis of this point.

He considered that payment was also an important feature, and in payment was the question as to profit or discount to the builder. In every specification and estimate which was given by a firm of concrete people, they ought to include a specific sum for this purpose. The builder was entitled to a sum, because he had lots of little things to see to and had a little responsibility, and it would be only fair to him to have a little return. Five per cent. ought to be added on.

Contracts.—With regard to contracts, if the amount of the contract for reinforced work was not serious, there was no reason why it should not be amalgamated in the general bill; but if the work was large, he agreed with Mr. Serraillier that the contract should be made direct.

MR. MORITZ KAHN.

Reinforced Concrete.—Mr. Kahn said he noticed that Mr. Serraillier made the mistake of crediting the Continent as the cradle of reinforced concrete. Monier is supposed to have invented this construction. As a matter of fact, an Englishman used a type of reinforced concrete at the time when Monier was still a small boy. The first records of English reinforced concrete dated back to 1831. He thought it some time about 1877 when Monier was first heard of.

Responsibility.—The speaker agreed that the responsibilities of construction should be apportioned to the various parties in ratio to the amount of work done. If an engineer prepared the designs let him assume the responsibility If a contractor supplied the labour and materials, his should be the responsibility for such portion.

An accident resulted either from faulty design or faulty labour and material. Drawings could always be checked. If found correct, the fault lay in the execution. He thought Mr. Serraillier asked too much by requesting the client to be responsible for the payment of reinforcing steel supplied to a contractor.

Preparation of Designs.—Referring to the expense involved in the preparation of estimating drawings, Mr. Kahn said that every time a scheme was prepared, a certain amount of money was spent. The money that is so spent was added up at the end of the year, and went to increase the percentage of establishment charges, which percentage must be added to every tender sent out the following year.

Copying of Designs.—Mr. Serraillier's statement regarding designs of competing firms being passed around was, unfortunately, only too true, and he thought that such a procedure on the part of an owner, architect, or engineer was just cause for legal proceedings.

PROFESSOR HENRY ADAMS, M.Inst.C.E.

Specialist Firms.—The chief point in the paper was the supremacy of the specialist contractor, who combined in himself the designer, the constructor, and the superviser. As a consulting engineer, Professor Adams demurred to the combination of offices; and also on general principles, because it was like combining the offices of cashier and auditor, etc.

Failures.—In two or three places the author spoke of engineers and architects as being able to make mistakes with possible loss of reputation, but no money loss; but speaking of the specialist in concrete work, he was ready to take the responsibility. There have been instances where architects, engineers, and quantity surveyors have all had to put their hands into their pockets to save publicity. The law stood this way: that a professional man was not liable for errors of judgment, but for negligence, and that was the distinction between the cases where an engineer or architect was or was not responsible.

Factor of Safety.—The factor of safety was not a definite and fixed amount; it might be called 5 when it was really 3. The factor of safety was a figure that should cover all contingencies, which vary in every case, and it was not as if perfect material, perfect workmanship and perfect design were to be had. If it was possible to rely on all that was being done, a factor of 2½ would probably be safe for all circumstances.

Rules for Reinforced Concrete.—The regulations of the R.I.B.A. Reinforced Concrete Committee had been referred to. It was a good thing for the Concrete Institute to consider. He hoped they would simplify the formulæ, and take care that contingencies are properly allowed for. In all formulæ of that kind there was a tendency to be too theoretical, to consider that the work was perfect, whereas in practice the supervision of the men and the material could not always be relied on; and so some of these formulæ that were put forward were too finely cut for practical use.

Failures.—With regard to failures the workmanship was more often at fault than the design.

MR. HERBERT E. BROOKS, J.P.

Loans.—Mr. Brooks stated that from the suggestion made by Mr. Serraillier, he had come to the conclusion that a better result would be secured if the Local Government Board selected and appointed a Committee to deal with the loan question. A strong representation was made not long ago, but the President of the Local Government Board was exceedingly obdurate on the matter, and he doubted whether any Committee of the Institute that could be selected could produce any effect upon that gentleman's mind. He also stated that it had occurred to him that the line of lesser resistance might be to invite the Local Government Board themselves to select the Committee.

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MR. E. BENEDICT, M.Inst.C.E.

Responsibility.—Mr. Benedict stated he was impressed by the remarks of Professor Adams as to the factor of safety. He had had a great deal to do with concrete in his time, and was aware of the uncertainty of the quality of concrete in various cases. He considered that anybody who was interested in reinforced concrete should not only be responsible for the concrete, but should also be responsible for the steel.

MR. A. B. JOSCELYNE, A.M.Inst.C.E.

Mr. Joscelyne, referring to the author's statement that the contractor had ample chance of checking quantities before tender, said he would like to know, if detailed drawings were not submitted, what chance the contractor had of checking quantities?

Another question referred to what Mr. Etchells said about the Institute working in unison with the R.I.B.A. to amend the rules and regulations for designing reinforced concrete, which all specialists could work to. Could the specialists be depended upon to work to the amended rules? At present, in minor steel construction, he did not think there was an engineer who would be dictated to by any Committee as to how to design a steel girder. Could the concrete expert be dictated to by the Committee of the R.I.B.A. or the Institute as to how he should design reinforced concrete?

MR. ETCHELLS, M.Phys. Soc., A.M.I.Mech.E.

Referring to the point raised by Mr. Joscelyne, it was for the reason that one could not expect the contractors to be dictated to by a technical or architectural society, that he suggested it might be necessary to have legislation to prevent unfair competition; because if 90 per cent. worked fairly to a proper basis, there would be perhaps 1 out of the remaining 10 who would undercut the rest, and secure the orders on an insufficient factor of safety.

MR. EDWIN O. SACHS, F.R S., Ed. (Chairman of Executive).

The Chairman said he desired to join with those who had spoken in thanking Mr. Serraillier for the very excellent and interesting paper.

The Practice of Reinforced Concrete.—There was, as all knew, a very great amount of confusion at the present moment in the practice of reinforced concrete work, and he used the word "practice" advisedly as it covered the subject matter of Mr. Serraillier's paper best. He, however, thought, as he had said before, that this confusion would disappear as architects and engineers became more acquainted with the subject of reinforced concrete, and realised both the advantages and limitations of certain forms of contracts, tenders, specialist designs, etc.

Mr. Sachs saw fully what Mr. Shields intended when he spoke of the possible extinction of the reinforced concrete specialist, and he did not share those views in the light in which they had been taken by the members of specialist firms present. He was under the impression that the future would bring with it a change in procedure. The architect would prepare his designs for reinforced structures more fully as he understood more about the subject. The younger generation of architects would know the subject thoroughly by the time they were in practice, say, in ten years' time, and it was then that the public would see a really general use of reinforced concrete, and specialists would have ample to do, even if in a very different form than at present.

Specialist Firms.—Specialists would then have good specifications to work upon, and those who sell specialised articles, like bars, would make those bars to specification. The result would be very much the same as was to be seen with steel frame construction. There would be a recognised practice, based, very much as it is at present in steel work, on standards, and to a certain extent on legislation or on rules, but the standards would be the predominating factor, and would be arrived at after joint consultation between the professions and the industries concerned. The architect would know what he wants in detail; the engineer likewise; and the specialist would really be having rather an easy time, for he would become the constructor, and a constructor more than a designer, and it would not be expected of him to design to the extent he has to now to get work at all. To-day, specialists have to do a great amount of pioneer work, but if we come to think of it seriously they have also had to do a great deal of work which the architect or the engineer ought to have done of his own accord in his own office.

Failures.—Regarding the point as to failures, he was one of those who believed that the precise publicity of the cause of failures would be an advantage to the development of reinforced concrete. The unknown is always worse than the known; and to know precisely what are the very points in which reinforced concrete has its dangers, and know what is to be avoided, meant an avoidance of failures, and that those precautions would be taken that were really necessary.

Responsibility.—As to the legal aspect of the responsibility in France, Mr. Sachs pointed out that the code of Napoleon obtained there, and that the builder or contractor was held responsible until he proved that he was not guilty of negligence.

Payments and Discounts.—Regarding the financial question of payments and discounts, if the contractor has to refer designs to the sub-contractor, and make things easy for him to do his work properly, it was only fair that the general contractor should receive from the employer some payment for his trouble, and there should be provided from 5 to 7½ per cent. payable by the employer to the contractor for his trouble. On no account, however, should the sub-contractor tolerate that the general contractor thereupon make a further deduction of 2½ per cent. or more for cash, for the sub-contractor is entitled to the full amount of his certificate without deduction of any kind whatsoever.

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Loan Periods.—Regarding the proposal of Mr. Brooks that the Institute should approach the Local Government Board as to the possibility of instituting a Committee of Enquiry on matters relating to reinforced concrete, Mr. Sachs stated that he welcomed the suggestion, and that the matter should have the fullest consideration of the Council.

MR. LUCIEN SERRAILLIER.

The Lecturer's Replies.—Mr. Serraillier said he noticed all the specialist representatives were of the same opinion, while the engineers and architects were of another opinion. That was to be anticipated.

Mr. Shields spoke of the paper as "The Bitter Cry of the Distressed Specialist." He was sorry his paper should be considered in that light, for it was merely meant as an indication of the difficulties they had to encounter at the moment, and which will be overcome. They had no intention whatever of disappearing; on the contrary, they had come to stay, and were doing very well. With all these difficulties they were getting on all right, the difficulties would be less when the situation was better understood. Architects, engineers, and clients in general do not quite realise the position, but they would join later on in facilitating a better understanding. As Mr. Sachs pointed out, it was merely a change of procedure, and not quite of disappearance.

Regarding failures to which the Local Government Board have referred, Mr. Workman spoke of structures which have been in France for thirty years. He thought that ought to be sufficient indication that these buildings could stand. If they stood in France, they could stand in England.

Referring to Mr. Scott's remarks, Mr. Serraillier said he understood Mr. Scott to infer that the architect or the engineer ought to design the structure and get out the quantities, and then invite tenders and let the contractor select the specialist for the specialist systems. He would say there were so many tons of steel in the structure, so many cubic yards of concrete, and decide on the specialist systems.

Mr. Scott replied in the affirmative.

Mr. Serraillier stated that as the weight of the steel would depend on the reinforcing material adopted, it was not feasible to estimate the weight of steel before deciding upon the system to be selected.

Mr. Scott replied that he would limit himself to ordinary commercial round bars, and continued that he found that special kinds of bars were being used by irresponsible people, and failure might be courted by using those bars; and if the same ones were used one might not only upset the client, but, if the calculation were wrong and the building goes, one would hold a very much worse position than if one had been brought up for manslaughter.

Mr. Serraillier asked if he confined himself to systems, and not to bars.

Mr. Scott replied in the affirmative.

Mr. Serraillier stated that if anything that was worse, because the systems differed so much. One system might employ more steel than another. Surely, before the quantities were got out the system must be decided upon, or else there would be different quantities for each system.

Mr. Scott replied that he had his basis of steel work before the tender was accepted. Quantities were adjusted to the necessary amount of steel required. The result of the tenders was not reported to the client until each complete system was judged.

Replying to Mr. Munro's statement that the responsibility should be taken by the specialist, Mr. Serraillier said that he agreed in the case of a specialist like the firm Mr. Munro was connected with, who carried out the whole work; but there are specialists who confine themselves to part of the work, and that is why he wanted a differentiation of responsibility. If a specialist firm only made the design, they should only be responsible for the design; if they take the position of contractor, they ought to be responsible for the work. Then there was the question of the discount to the builders, and the suggestion that the specification should include 5 per cent. That would be all right if some understanding could be arrived at beforehand about it.

Mr. Kahn said it was an Englishman who discovered reinforced concrete. The Lecturer meant to imply it was on the Continent that it first took its development, and not necessarily that it was initiated there, though he was certainly under the impression that Monier was the first to use it. Regarding co-operation of specialists to discuss certain questions, he agreed as to its advisability. The only reason why this had not taken place was that it might give amongst engineers and architects the idea of some ring or trust.

Professor Adams said he did not believe in the combination principle as a logical one—some thought it logical and others illogical—as to the designs, execution and materials being carried out by one party. Professor Adams did not agree to that because he was an engineer. Of course, that explained his objection. Regarding the question of responsibility, his point was that the specialist was asked to be responsible for errors of judgment, and a mistake in quantities was an error of judgment; and that was where it came hard upon them.

Professor Adams said the factor of safety might be 5 or 3. That was precisely his point, one never knew whether the treatment was the same on one job for all competitors, so that it was advisable they should be reduced to the same denominator.

Mr. Brooks suggested that the Local Government Board should be approached by the Concrete Institute with a view to the appointment of a Committee to inquire into this question of loans, and he said the President of the Local Government Board is very interested in the question. The lecturer was afraid the President of the Local Government Board was entirely in the hands of his technical advisers, and that was where the hitch occurred and the difficulty lay. Mr. Brooks suggested this would be the line of least resistance; the Lecturer hoped that at least it would not be the line of passive resistance.

The Chairman thereupon announced that the meeting terminated.

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED

REINFORCED CONCRETE RAILWAY BRIDGE FOR THE GREAT CENTRAL RAILWAY.

SLOWLY but surely the advantages offered by reinforced concrete for the building of railway bridges are becoming officially recognised in this country. Many important structures of the same class have been constructed in America, on the Continent, and elsewhere, but only within the last year or two has reinforced concrete been applied to the design of bridges for main-line rolling stock in this country.

Why there should be so much delay in employing reinforced concrete for railway bridge work in this country is scarcely to be understood at a period when the directors of our great lines are all so anxious to economise in expenditure, but the fact remains that some of the leading civil engineers in charge of these lines appear to be allowing their prejudices to overcome their reasoning, and it is only on quite a few lines that real enthusiasm is to be found among the engineering staff for adopting promptly what must necessarily become an everyday material in modern railway work.

Notable exceptions who have employed reinforced concrete for railway work are the South Western, the Great Western, the North Eastern, and Great Eastern Railways, and we have from time to time dealt with work on these lines.

One of the most recent examples is the reinforced concrete girder skew bridge at Immingham Docks, Lincolnshire, in which the Hennebique system has been applied. This bridge forms one of the series of four railway bridges in course of completion for the Great Central Railway.

Fig. 1 is an elevation of the structure in question, which carries two sets of metals over an existing railway line, the length of the bridge measured along its central axis being 88 ft.

Fig. 2 includes a half sectional plan on the line AA and a half sectional plan on the line BB, the levels of these section lines being explained by the vertical section *Fig.* 3.

As will be evident from these drawings the entire work is supported on pile foundations connected by beams and continuous slabs. The piles were rendered necessary by the soft and compressible nature of the soil, and having been moulded on the site in the usual manner, were driven to refusal by a 40 cwt. monkey.

These piles, measuring 12 in. square in cross section with an average length of 35 ft., are disposed in double rows connected longitudinally and transversely by reinforced concrete beams 9 in. wide by 21 in. deep, and 8 in. wide by 14 in. deep

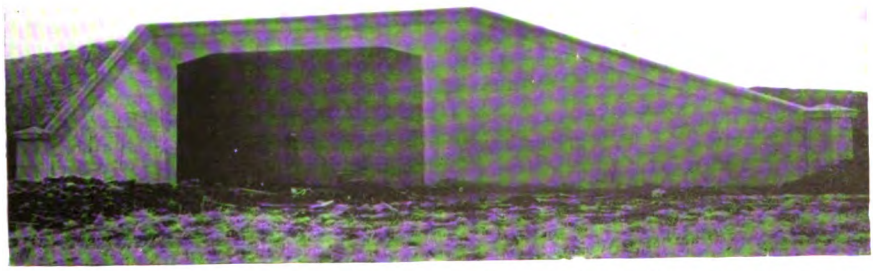

FIG. 5. REINFORCED CONCRETE GIRDER SKEW BRIDGE, IMMINGHAM DOCKS, GREAT CENTRAL RAILWAY.

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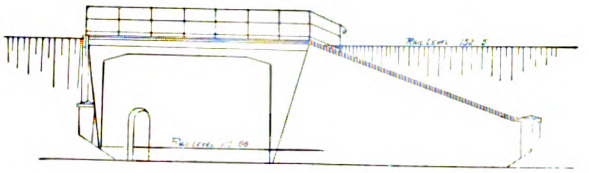

FIG. 1.

FIG. 4.

Section through Wing Wall.

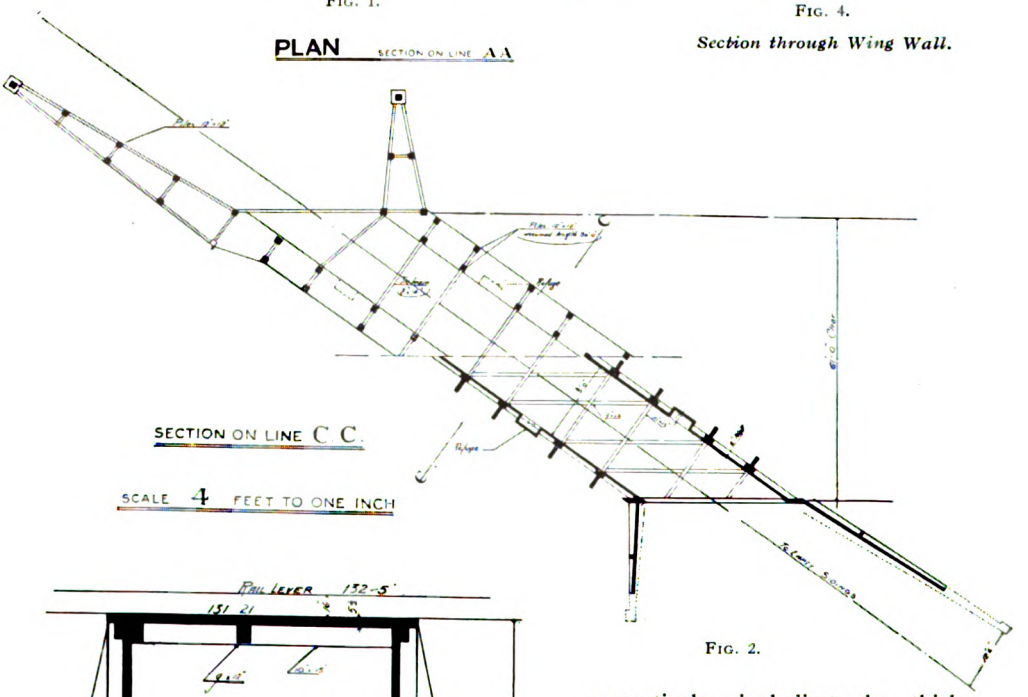

FIG. 2.

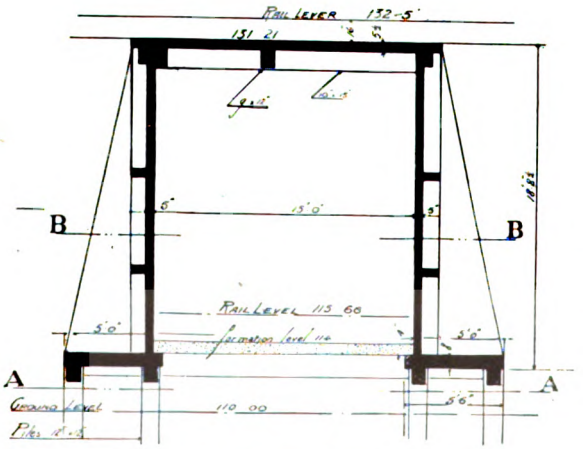

FIG. 3. REINFORCED CONCRETE GIRDER SKEW BRIDGE, IMMINGHAM DOCKS, G.C.RY.

respectively, including the thickness of the 8-in. foundation slab. In addition the two parallel foundations are connected by tie beams 8 in. wide by 14 in. deep at intervals varying from 8 ft. to 12 ft. apart; these ties being connected in turn by a continuous 9-in. slab forming a solid foundation for the permanent way of the lower line.

From the inner side of the foundation slabs rise two 5-in. walls stiffened by counterforts and horizontal ribs, the position and dimensions of these members being indicated in *Figs.* 2 and 3.

Although this method of construction is extremely light in comparison with ordinary masonry, it is of great strength and rigidity, and its lightness carries the double advantage of reducing cost, and at the same time of reducing load on the foundation.

It may be pointed out that four refuges, 4 ft. long by 1 ft. 6 in. deep, are provided in the side walls, their positions being shown in *Fig.* 2.

The wing walls of the bridge (see *Figs.* 1 and 2) are of generally similar character, as represented by the section given in *Fig.* 4.

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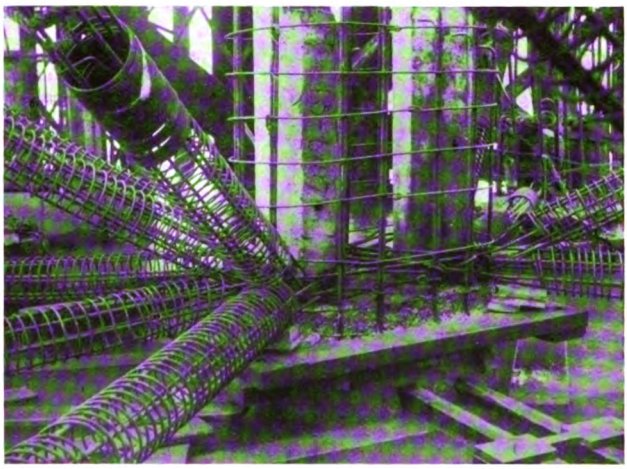
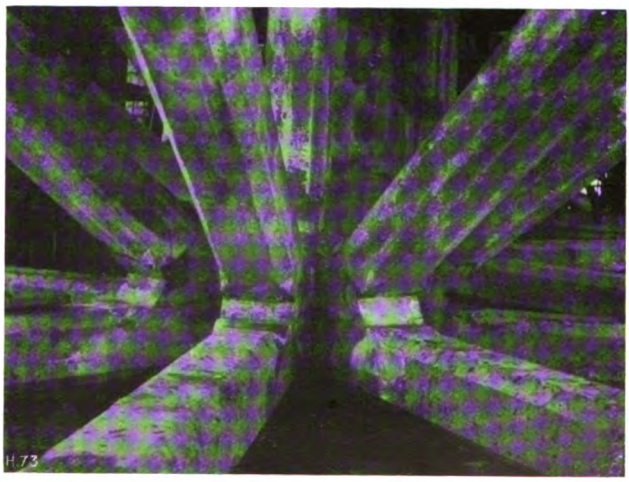
Fig. 5 is a view of the completed bridge, which was calculated for the rolling load of 54 tons on a wheel base of 13 ft., or three pairs of concentrated wheel loads of 18 tons each, spaced 6 ft. 6 in. apart centre to centre.

The bridge was designed by Mr. J. B. Ball, M.Inst.C.E., engineer for new works to the Great Central Railway, for whom details of the reinforced concrete work were prepared by Messrs. L. G. Mouchel & Partners, Ltd., while the work is being carried out by The Yorkshire Hennebique Contracting Co., Ltd., of Leeds.

RECONSTRUCTION OF JETTY HEAD IN REINFORCED CONCRETE AT THAMES HAVEN.

The new structure has been built to replace an old T head composed of cast iron piles with wrought iron bracings, the greater portion of which was carried away in a collision by a large vessel. After the collision part of the old structure remained, and this, with the addition of temporary wood piles, was used as staging from which to construct the new work. The jetty head is 136 ft. long by 32 ft. wide. The deck level is 5 ft. 6 in. above high water spring tides and about 45 to 48 ft. from the bed of the river; the spring tide range is about 18 ft. Vessels up to 7 or 8,000 tons burden are accommodated, so that the structure was needed to be specially strong in cross section, in order to take the shock resulting from such large vessels. The jetty head was required to be designed as a complete structure in itself and independent of the approach jetty, which could not be reckoned on for support. It being impossible to fix concrete bracing below low water level it was decided to make the main support of the structure composed of two piles, which were surrounded by a reinforced concrete cylinder 5 ft. dia., and then filled in solid, so as to give great lateral stiffness to each support. A general plan and elevation is attached herewith. There are three main columns in the width of the structure, the centre column being midway between the outer columns, with horizontal and diagonal bracing in all directions. It will be seen that this method





THAMES HAVEN REINFORCED CONCRETE JETTY HEAD.
A pair of reinforced concrete piles and the bracing before and after concreting.

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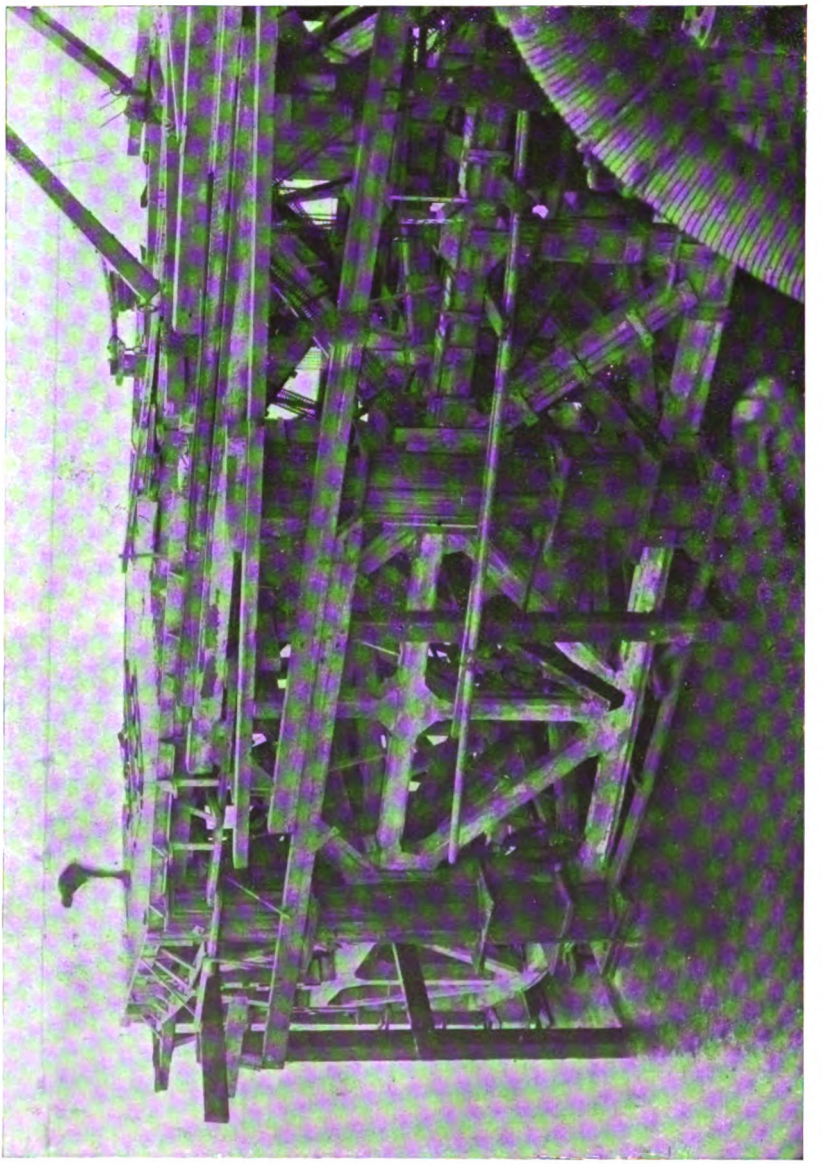
of construction and bracing has the effect of distributing all shocks over a large number of the columns, and thereby giving great rigidity to the structure.

The columns are 5 ft. dia. up to low water, after which they are reduced to an



THAMES HAVEN REINFORCED CONCRETE JETTY HEAD.
Showing the centering round reinforced concrete piles and bracing.

oval section of about 5 ft. by 2 ft. 6 in., and continued in this section up to the under side of the deck. All the horizontals and diagonals are also spirally and longitudinally reinforced, so as to take stresses of either compression or tension. Timber fenders are bolted to the columns to act as rubbers against the jars of ships.

The method of procedure in carrying out the work was as follows:—

Piles 45 ft. long were driven 18 to 20 ft. into the bed of the river in groups of

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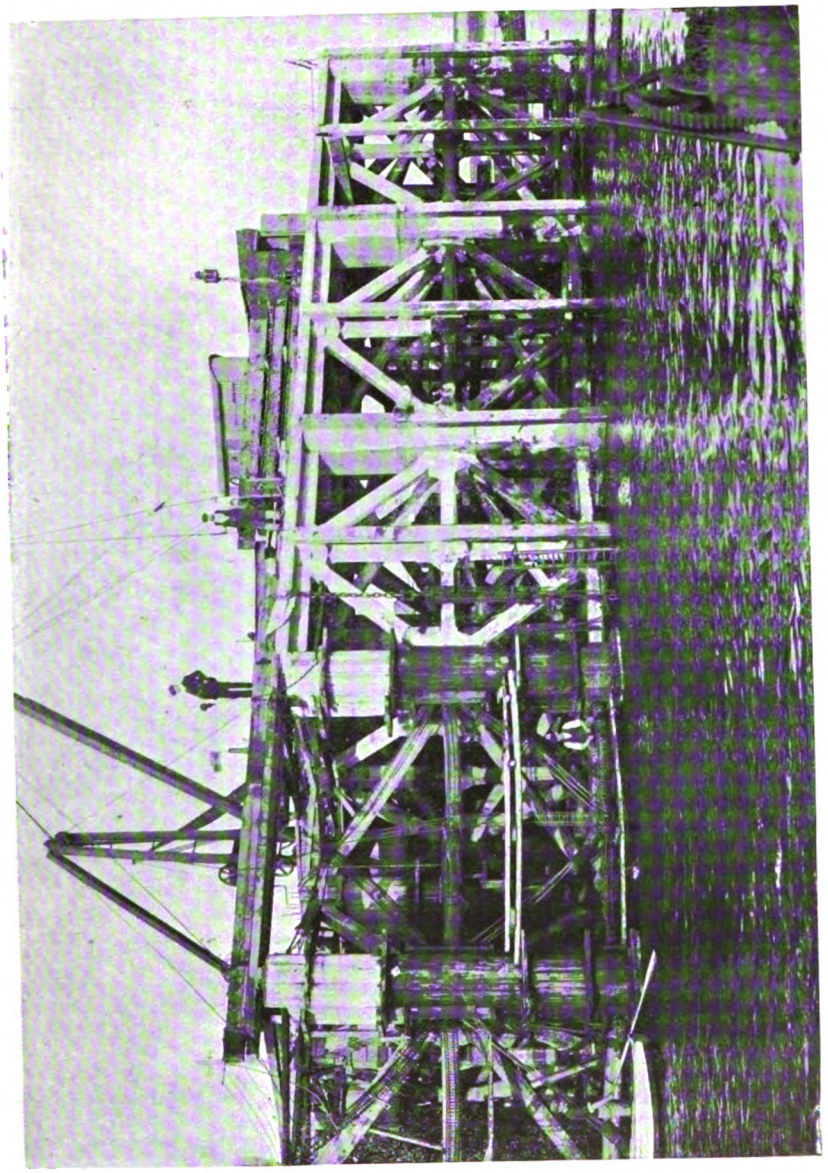
two, as shown on the plan; the temporary steel casting was then dropped over the piles and bedded about 2 or 3 ft. into the bed of the river. Inside this steel casing and over the piles an enveloping reinforcing, composed of longitudinal rods and hoops, was



THAMES HAVEN REINFORCED CONCRETE JETTY HEAD.
In course of construction.

dropped, and the casing was filled up with concrete 3 to 1, deposited through the water by means of shoots, to 3 ft. above low water level. The columns, braces, and deck were then built up *in situ* with the usual timber shuttering. Views of the work at various stages of progress are shown. In *Fig.* 1 is seen a pair of piles after driving with the enveloping reinforcing ready for the reception of the concrete. The photographic view also shows the reinforcing of the various braces.

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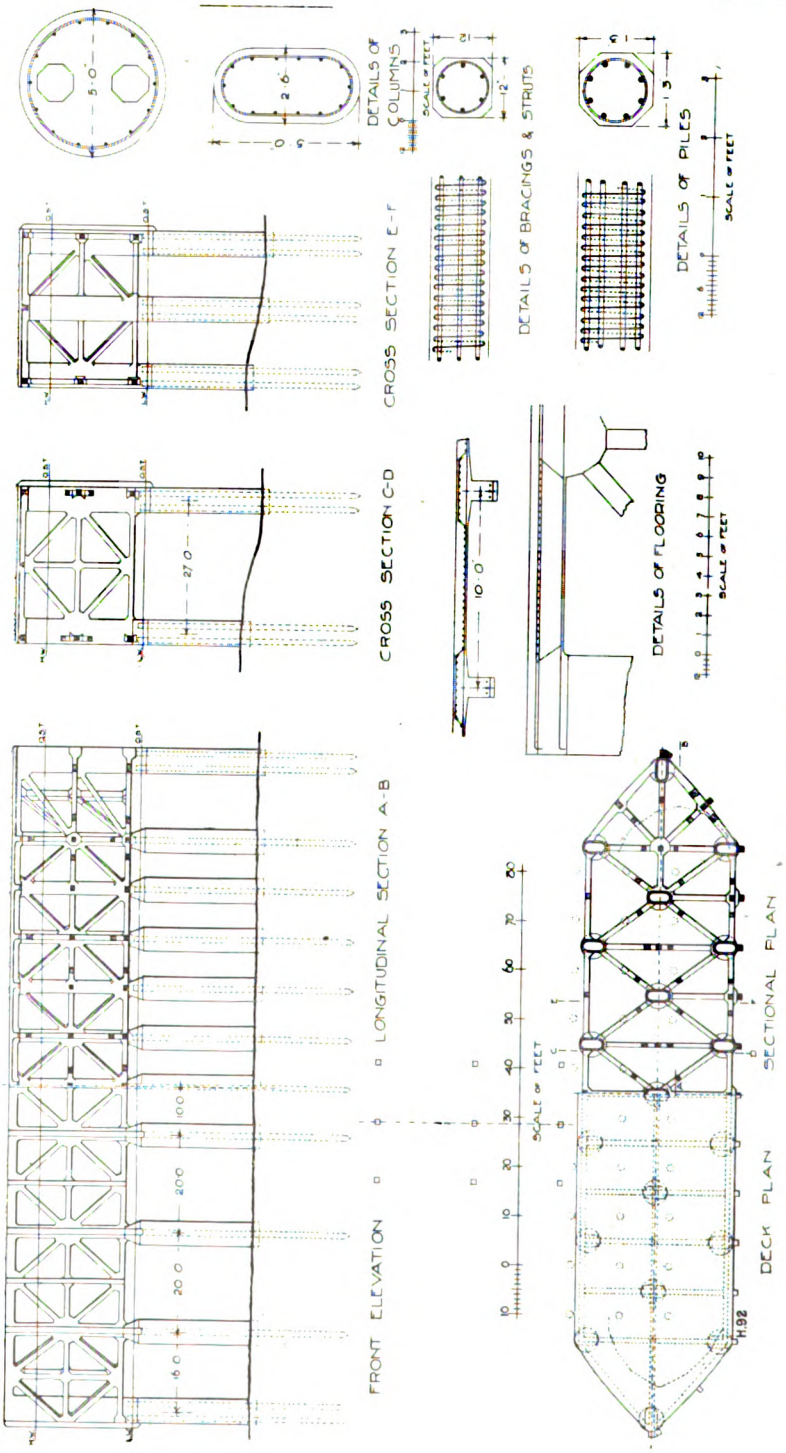

THAMES HAVEN REINFORCED CONCRETE JETTY HEAD.
Plan, section and details of construction.

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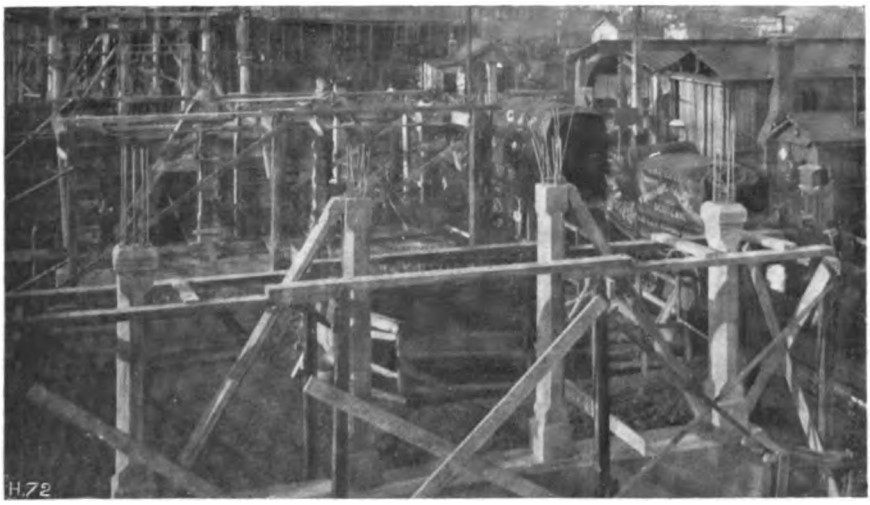
The temporary steel casing was made in two halves, with vertical joints bolted together, so that it could afterwards be taken away, when the concrete was set, by means of a diver unbolting the vertical joints. The piles were 15 in. dia. octagonal section, made on the Considère principle; the reinforcing was composed of $\frac{3}{8}$ in. dia. steel, spirally wound with 2 in. pitch, and 8 longitudinal rods of 1 in. dia. The strata of the ground into which the piles were driven is composed of Thames ballast with an overlay of about 4 to 6 ft. of soft, sandy mud.

The piles were driven with a 30-cwt. monkey, falling 6 to 7 ft., mostly with a timber dolly intervening between the head of the pile and the monkey, but, in some cases, with the monkey falling direct on to the head of the pile. The piles withstood this driving very well indeed, and, where the dolly was used, the head did not suffer in the least, although, in some cases, the piles were driven to a set of 100 blows for the last inch before they were regarded as being driven to refusal. In the cases of direct driving, without any dolly at all, the piles were simply broomed up for about 12 in. of the head in a similar manner to timber piles.

The cost of the work has been £4,500, but this includes a large sum for pulling down the wreckage of the old structure.

The progress of the work was necessarily slow, as it was imperative to keep intact



THE ANGEL ROAD REINFORCED CONCRETE BRIDGE ON THE GREAT EASTERN RAILWAY CO. in course of construction.

the remains of the old structure, so that boats could be brought alongside this, while the first half of the new work was constructed, and this, in turn, was used while the balance of the work was completed.

THE ANGEL ROAD BRIDGE.

THIS bridge, which was erected for the Great Eastern Railway Co., carries the public road over the railway in place of a level crossing.

The experience gained in the utility of reinforced concrete having been entirely satisfactory on this railway it was determined to carry out the whole of the work in this material, and it is one of the largest bridges and approaches in reinforced concrete in the United Kingdom.

The design is on the Considère system, and consists of 17 equal spans, three of which are on the curve, designed as continuous girders, 42 ft. 9 in. between the centres of bearing and 5 ft. 4½ in. apart, carrying a roadway 24 ft. wide, together with 2 ft. of footway on both sides, the remaining 6 ft. of the latter, together with the parapets, being supported by cantilevers.

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The flooring is 6 in. thick, weighing, together with the road metalling, ·77 tons to the super yd., to carry a load of $6\frac{1}{2}$ tons on a wheel 20 in. wide, this weight assumed as being transmitted through the road metalling at an angle of 1 to 1 and into the body of the flooring at an angle of $1\frac{1}{2}$ to 1, the total distributed super load being therefore 3·2 tons per super yd. For a 5-ft. $4\frac{1}{2}$-in. span 1 yd. wide the dead load is 1·8 super yd. × 0·77 tons = 1·4 tons. The super load is 1·8 super yd. × 3·2T = 5·76 tons.

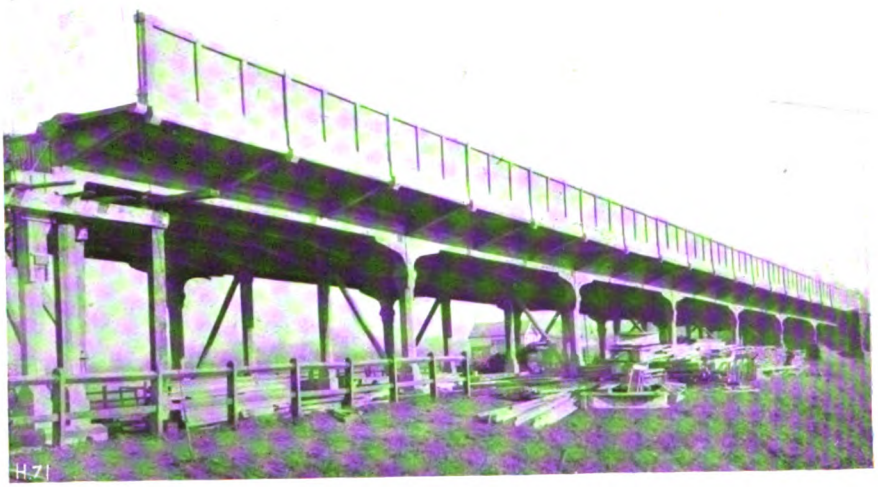
A full description of this bridge, together with plans showing the construction, was published on pages 196-199 of our July issue, Vol. III., No. 3.

REINFORCED CONCRETE BIN DIVISIONS AT VICTORIA DOCKS.

AMONG the many interesting works recently erected in this country are the bin divisions of the Grain Silo at the Victoria Docks, and which is noteworthy on account of its great height.

The dimensions are 80 ft. by 80 ft. on plan divided into 81 bins, each 7 ft. 7 in. by 7 ft. 7 in. by 90 ft. high, all the bins, the walls and the deckings of reinforced concrete being 5 in. thick.

The architect for the work was Sir Alfred Gelder, F.R.I.B.A. The whole of the reinforced concrete work was designed by Mr. E. P. Wells, and the contractors for the same were Messrs. F. Bradford & Co., of Homerton, N.E.



THE ANGELROAD REINFORCED CONCRETE BRIDGE
after the centering had been removed.

The work was started on January 2nd, 1908, by the making of the automatic shuttering for the reinforced concrete work. The concreting was commenced on January 15th, and the contractors were clear of the building on July 6th of the same year.

The Silo has 81 bins, the majority being 8 ft. centre to centre, and the concrete walls, as stated above, are throughout of 5 in. thickness. Where the walls bear upon the steel girders, forming hopper construction, the same are thickened out to $6\frac{3}{4}$ in.

The proportions of the concrete throughout were 5 to 1—viz., 3 parts crushed Thames ballast to pass a $\frac{3}{4}$-in. mesh, 2 parts sand, and one part Portland cement of the Hilton Anderson Brand. The steel throughout had a factor of safety of 3 to 1, the concrete in tension being ignored.

The maximum compression of the concrete at the bottom of the walls on all the bins or silos, and including the weight of the concrete, was 360 lb. per sq. in. The total capacity of the bins is 10,000 tons. The top of the bins is covered over with a reinforced concrete floor 5 in. thick and designed for a safe working load of $\frac{3}{4}$ cwt. per sq. ft.

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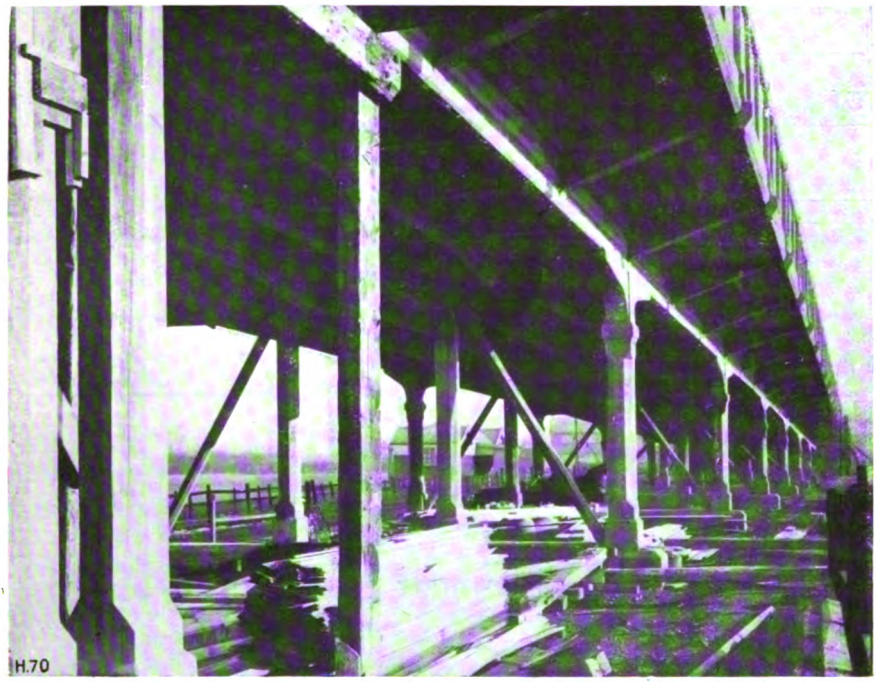

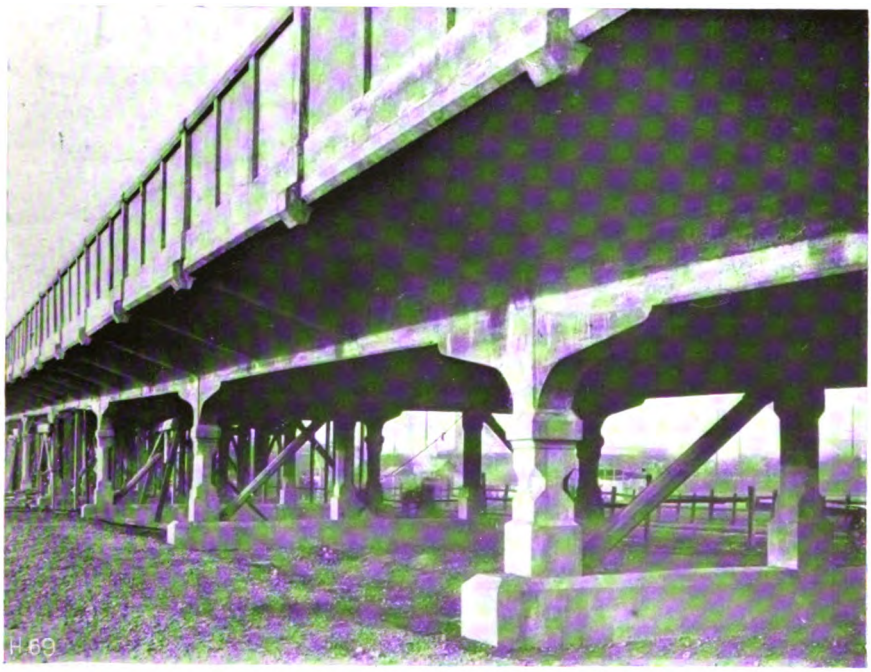

THE ANGEL ROAD REINFORCED CONCRETE BRIDGE.
Two views of the practically completed structure.

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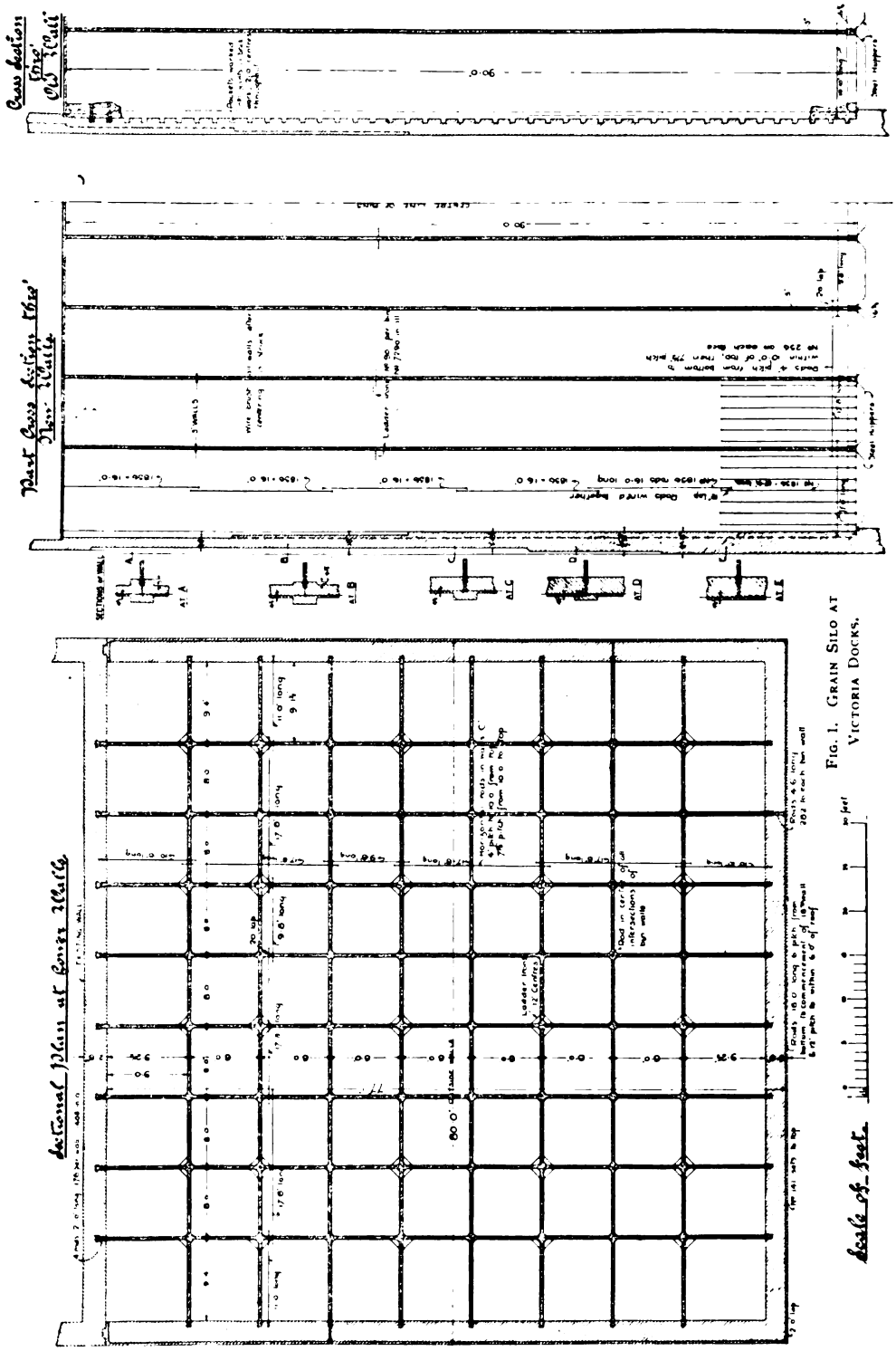

FIG. 1. GRAIN SILO AT VICTORIA DOCKS.

PLAN OF SILO AND PART SECTION SHOWING REINFORCED CONCRETE BIN WALLS

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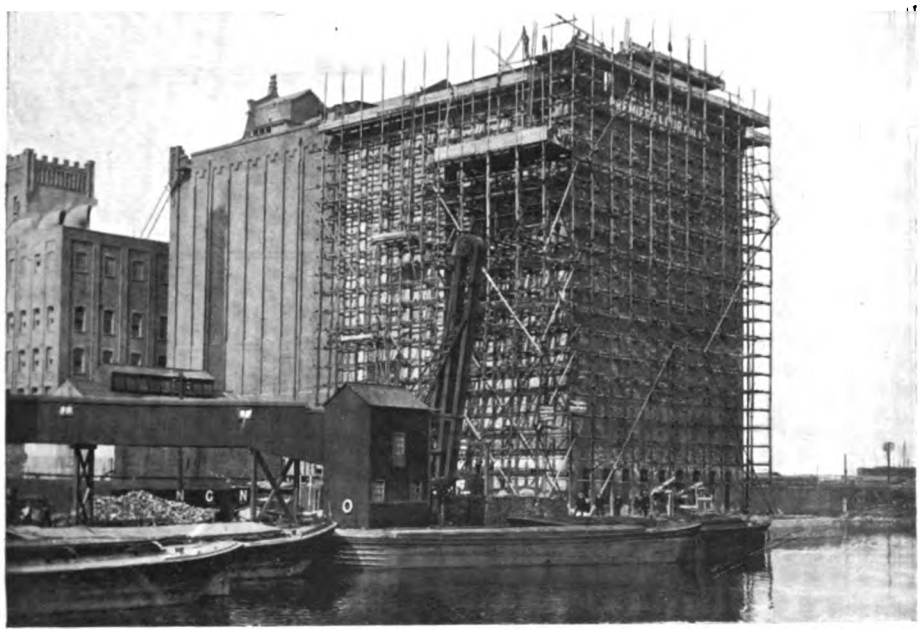
Access to all the bins is provided by trap doors and ladder irons in the angles (see *Fig.* 1) at 12-in. centres, which enables a man to descend from the top to the bottom. The whole of the bins are carried upon steel girders, which in turn rest upon cast iron columns. The hopper bottoms are made of steel throughout (see *Fig.* 1).

The foundations of the building are carried on a huge raft extending over the whole area, which rests upon timber piles driven to a secure foundation.

The external walls of the silo are composed of brickwork of varying thicknesses, the whole being reinforced with steel rods, and special arrangements were made for tying the same into the concrete bin walls (see *Figs.* 1 and 3). Special arrangements had to be made for fastening the new bin walls on to existing bin walls, which can be seen to the left of the illustration, and which contained bin divisions constructed of timber.

For the internal bin walls the reinforcing rods are carried up from the hopper bottoms at 4-in. pitch to within 10 ft. from the top, and the pitch is then varied to $7\frac{1}{2}$ in. For the outer divisions connected up to the brick walls the pitch of the rein-



GRAIN SILO AT VICTORIA DOCKS.
A general view during construction.

forcing varied three times, the main pitch being carried up to about 60 ft. from the bottom, then it varied between that and 80 ft., and then again from 80 ft. to the top. The total height of the concrete bin walls is 90 ft., and the total height of the building 106 ft.

The rate of progress of building during the fine weather was 15 in. of concrete a day, but as a rule this was too fast for the bricklayers, who could not keep pace with the work. Frost delayed the work to a slight extent, and there was a delay in waiting for steel roof principals, the tie beams of which are built into the upper portion of the concrete bin wall (see *Fig.* 2, section through floor).

Unfortunately, owing to the fact that the brickwork kept pace with the reinforced concrete, it was impossible to obtain an interior view.

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THE BERW ROAD BRIDGE.

THE new reinforced concrete road bridge over the Taff at Pontypridd is now open to the public.

The bridge was designed by Messrs. Mouchel & Partners, of Westminster, on

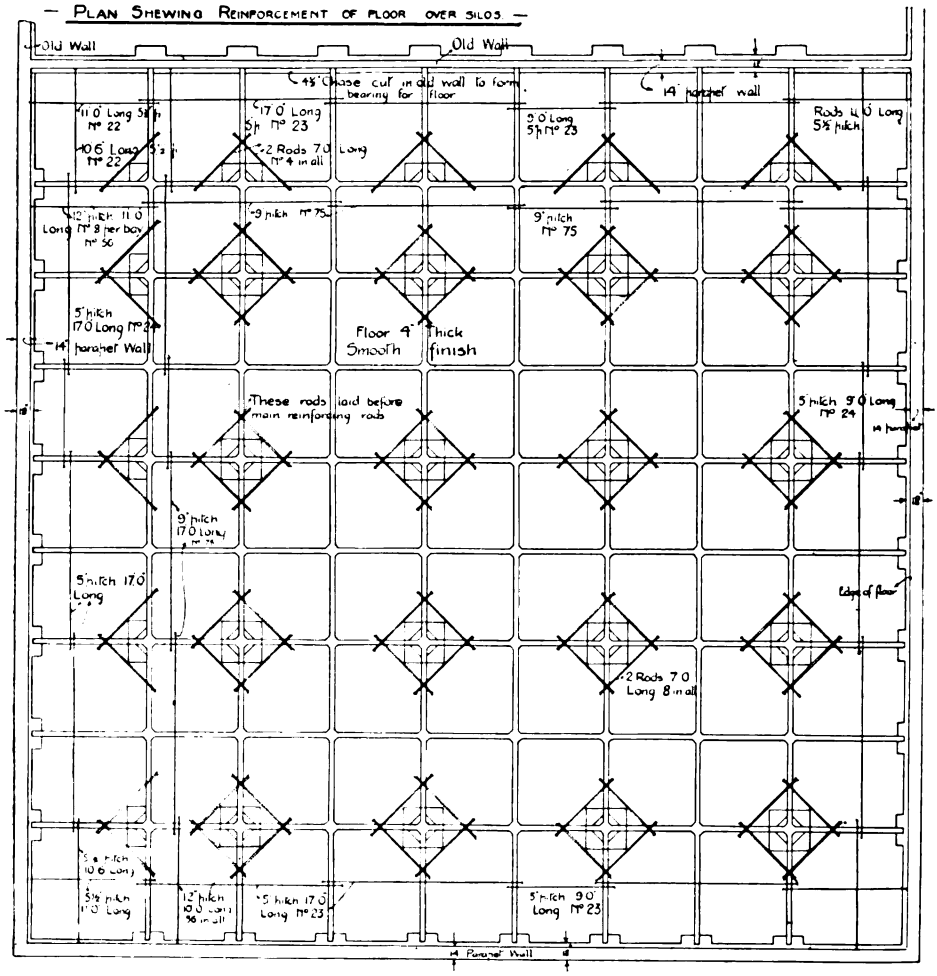

FIG. 2. GRAIN SILO AT VICTORIA DOCK.
Plan showing reinforced concrete floor over bins.

the Hennebique system, in conjunction with Mr. P. R. A. Willoughby, surveyor to the Pontypridd District Council, the contractors being Messrs. E. H. Page and Watkin Williams, of Cardiff.

The bridge was tested under a total load of 40 tons on the main arch, the deflection registered being barely one-eighth of an inch. The main arch has an expanse

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of 116 ft., the land abutments at each side being 26 ft. each, giving a total length of 175 ft. It is, up to the present, the largest reinforced concrete single span in Great Britain.

The difficulty of bridging such a span, together with the fact that considerable floods are experienced on the Taff at times, makes the work a notable one, and though the question of a stone and steel bridge was discussed, it is satisfactory to find that reinforced concrete has again proved economically superior, while there will, of course, be practically no cost for maintenance.

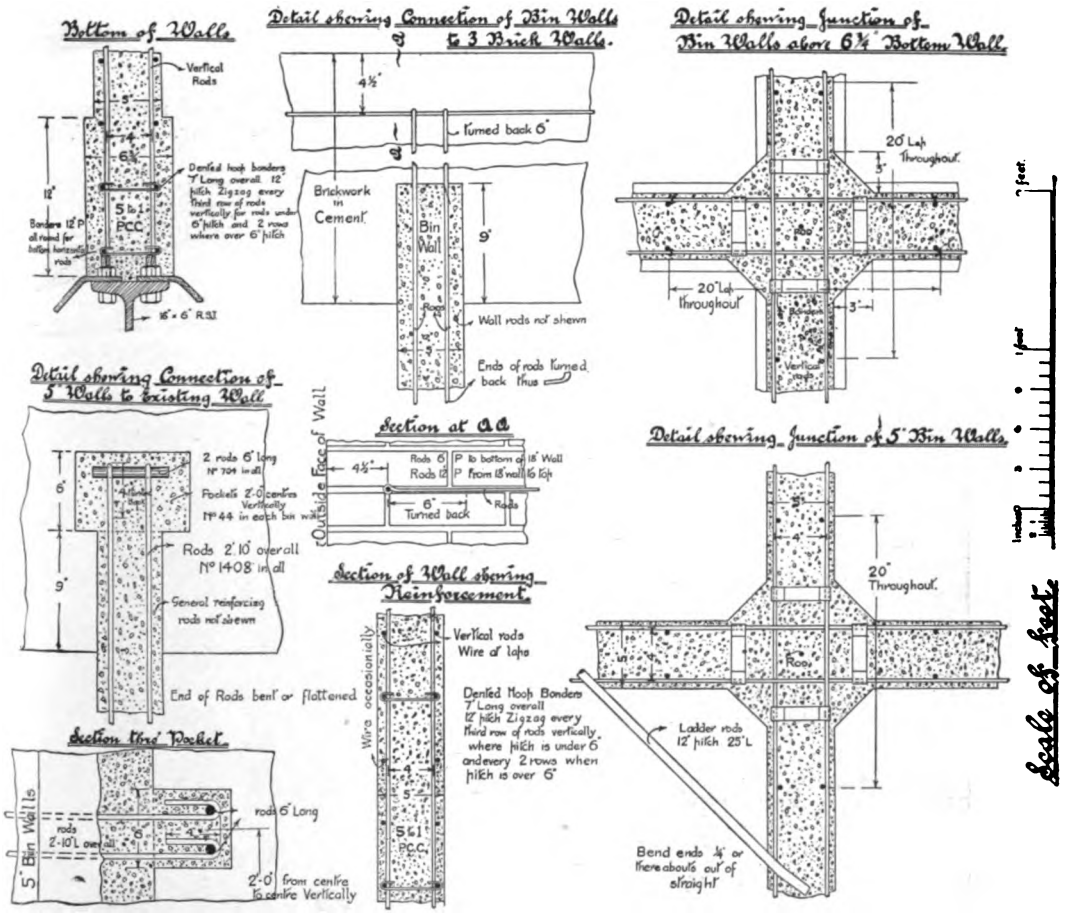

FIG. 3. GRAIN SILO AT VICTORIA DOCKS.
Details showing construction of reinforced concrete bin walls.

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NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

REINFORCED CONCRETE FENCE POSTS.

In our November issue we presented some illustrations and particulars of reinforced concrete fence posts which had been made from the registered designs of Mr. E. F. W. Grimshaw, and erected by him at West Mill, Buntingford, Herts.

The first illustration on this page now shows a collection of posts of various designs built to meet the various strains that may be brought against them. In all his experiments the designer has endeavoured to keep the material away from points which do not specially require it, in order to strengthen the parts which are subject to the greatest strains consistent with the different varieties of ground in which the posts are erected. These reinforced concrete posts lend themselves to being treated in this way better than posts of any other material, and the additional expense is little, if any, greater than making the square straight post. It has also been proved to be a great advantage.

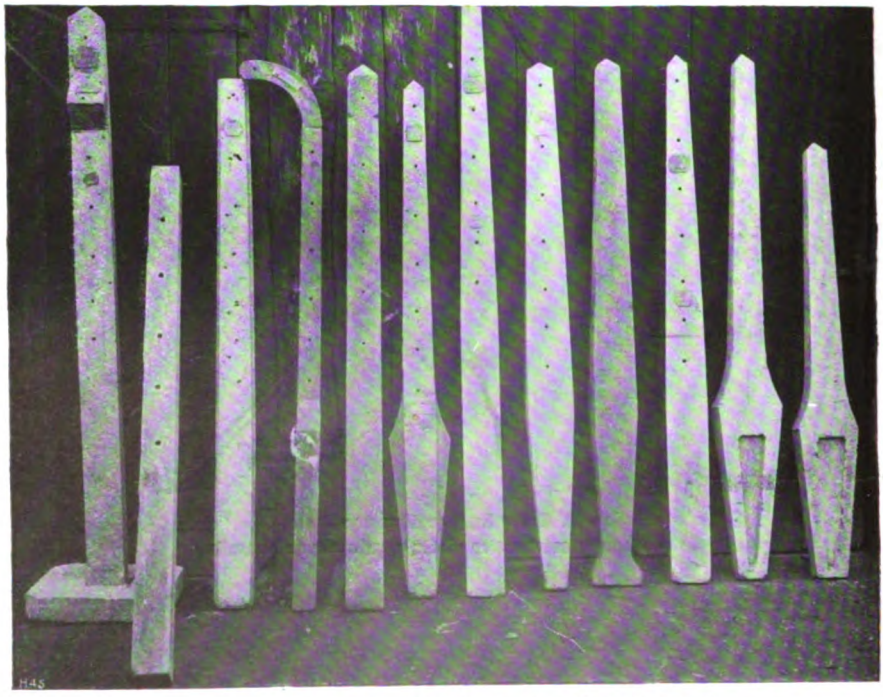

Fig. 1. Reinforced Concrete Fence Posts of Various Designs

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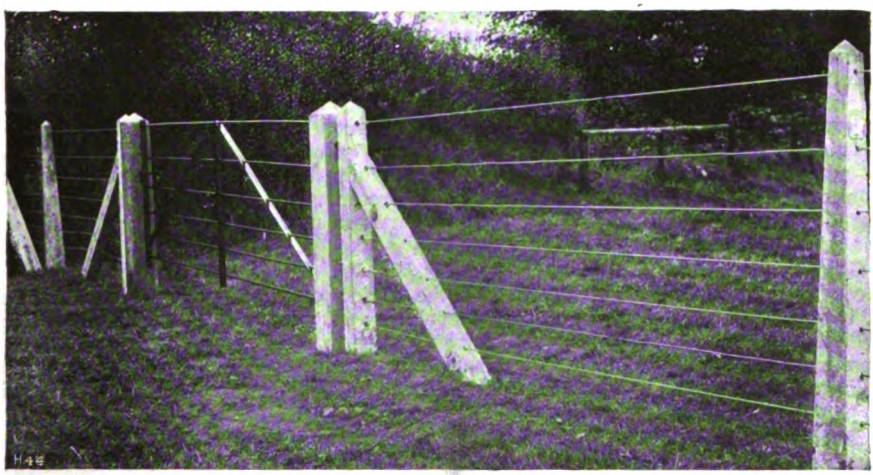
The designer also considers that the method of placing the reinforcement makes a substantial difference to the strength; though, of course, it is not possible to calculate the strains in the same way as the strains in reinforced concrete buildings can be allowed for. Their chief utility lies in their ability to withstand a heavy pushing strain from almost any direction, though they should also be able to stand a certain amount of hard knocks, but for places where they would be liable to receive constant hard usage, they would have to be made much stronger than any shown in these illustrations.

For ordinary railway fences or field and estate work they will be found hard to match in price, appearance, or lasting power, and with special regard to railways,



Figs. 2 and 3. Reinforced Concrete Fence Posts at West Mill, Buntingford.

owing to the burning of wooden fences, and to the attacks of insects in certain climates, after a certain number of years the saving would be found to be enormous. In addition, they are of no value for any other purpose, and would not therefore be stolen for firewood, etc.

Fig. 2 shows a fence about 150 yards in length, with 6 ft. posts similar to the third post from the right in *Fig.* 1, and seven wires. The posts are 5 in. square on ground level, and 2½ in. by 2½ in. at top. The spots on the posts are the patent and registered design numbers. The gate posts shown in *Fig.* 3 are at the far end of the same fence.

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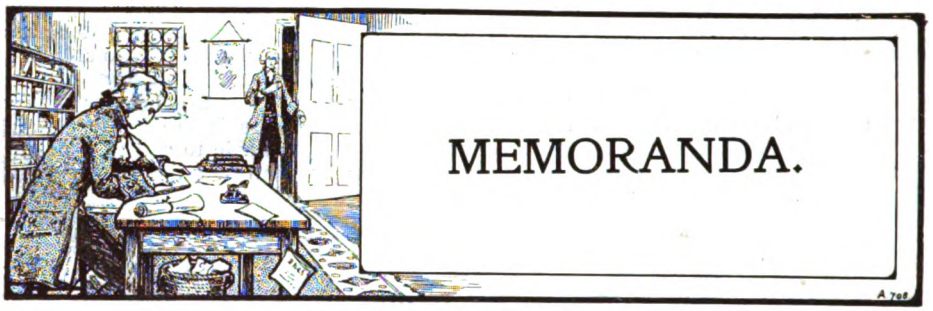

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

LECTURES.

Architectural Association.—Mr. John H. Markham, in his paper entitled "Reinforced Concrete," and referring to the composition of concrete, stated: "It is essential that the aggregate be composed of a material which does not contain acids capable of corroding the metal, and for this reason coke breeze and furnace slag must be used with caution, if at all. The best materials are: crushed ballast, broken brick, granite chippings, and broken stone; though limestone cannot be recommended where great fire-resisting qualities are required."

Another of the points very strongly brought out is that architects should endeavour to evolve their own designs, and not be too dependent on specialists. The possibilities of reinforced concrete are very far from being fully realised.

Mr. H. D. Searles-Wood delivered an exhaustive lecture on the subject of "Building Materials" before the members of this Association, dealing in succession with concrete and its various constituents, such as lime, cement, gravel, and sand, and then in rotation with steel, bricks and brickwork, tiles, stones, and timbers. He laid great stress on the results of experiments recently undertaken with regard to the strength of some of these materials, and pointed out at the same time that such tests must be most rigorously conducted. The lecturer also stated that continual supervision was of the utmost importance at the present time, when so much work is being done in concrete, a material with which it is more easy to tamper than any other substance employed in building works.

Clerks of Works' Association. — Mr. C. W. Denny, in a lecture entitled "Modern Building Methods," touched on the subject of reinforced concrete, and said that it would be interesting to trace the evolution of that form of construction from the flicked beam, double floors, double framed doors, etc., to the present method of concrete reinforced with steel. In conclusion, the lecturer remarked that if good buildings were wanted it was necessary to have good materials, good workmanship, and pay a good or a fair price.

Institution of Civil Engineers (Students' Meeting).—Mr. W. S. K. Mitchell (Stud.Inst.C.E.) read a paper on "Portland Cement: The Effect of Fineness with Aeration, with its Strength." An interesting point brought out by the paper was the large increase in surface area covered by a fixed quantity of finely ground cement over that covered by a like quantity of coarsely ground cement, thus enabling a larger amount of aggregate to be covered by the finely ground product.

Royal Philosophical Society of Glasgow (Architectural Section).—Mr. F. A. Macdonald, in a lecture on the "Uses of Reinforced Concrete," gave a short account of the origin and development of this method of construction, and also pointed out its merits in respect of economy in initial cost, durability, absence of vibration, and fire-resisting qualities.

Sir Cecil Hertslet's Report.—In our previous issue we referred to the fact that this Report was not in the hands of the public until late in the autumn of the following year. We regret that we were under a misapprehension as regards the date of the publication of the Report. The Report dated 1907-8 thus covers the last six months of 1907 and the first six months of 1908, and does not date from January to December as previously indicated by us.

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BOOKLETS, PAMPHLETS AND CATALOGUES.

"Everyday Uses of Portland Cement."—The Associated Portland Cement Manufacturers (1900), Ltd., are to be congratulated upon issuing a useful handbook under this title, and its contents should be particularly beneficial to the lay user of concrete.

The uses to which concrete is now being put daily by the ordinary householder and on country estates are increasing with great rapidity, and whilst much has been published in book form and the technical press giving the scientific and technical aspects of the various problems that have to be met with, very little has so far been published that is useful for rapid reference purposes for what we may term the man in the street.

The handbook, which we understand is obtainable on application to the publishers, is published at 2s. 6d., and comprises some 150 pages, containing numerous illustrations of a practical kind. The text gives useful hints in simple language, and whilst mainly devoted to the ordinary uses of concrete, there are also chapters on reinforced concrete and on concrete blocks.

If we would call attention to any special feature in the book, it is that care has been taken to also illustrate some of the more useful tools employed by those applying concrete, and some ideas as to useful forms and moulds.

The publication is well printed, and contains by way of appendix some interesting information as to the products of the Associated Portland Cement Manufacturers.

"Spons' Architects' and Builders' Pocket Price Book."—We are pleased to observe that the current issue of this very handy pocket price book contains a useful little chapter on reinforced concrete, and our only regret is that it is not somewhat more comprehensive, for having regard to the requirements of the architect and surveyor in practice who have comparatively small knowledge of reinforced concrete, it is just in a pocket book of this kind some concise data would be most useful for rapid reference. The Royal Institute of British Architects' Report of 1907 is given in full, and we think additional data would have been more in place. It is to be hoped that the chapter will be increased in the next issue.

The Construction of Modern Factories.—We have received from Mr. W. H. Brown an interesting pamphlet describing the application of certain systems of floor construction and reinforced brickwork panelling, advocated by him as being suitable in modern factory construction. The illustrations consist of some excellent general views of Messrs Rowntree's factories, with the design and execution of which the author was associated for some years.

The idea put forward in the pamphlet of the floors, walls, foundations, and fire-protective scheme being in one hand, certainly claims attention, as too great a sub-division amongst various sub-contractors is becoming a matter of serious concern among those who are responsible for a building.

Regarding the specialist features advocated, Mr. Brown's hygienic floor should have attention. It is a hollow floor, and as a hollow floor has certain hygienic advantages, which are detailed.

As to the system of reinforced brickwork advocated, it not only claims attention where brickwork panelling is to be inserted, but should have consideration wherever brickwork has to be used and is subject to vibration.

The pamphlet is well produced, and is quite worth reading. It is obtainable from the Standard Buildings, Leeds.

Messrs. Edward Le Bas & Co., of Billiter Street, E.C., have sent us a catalogue illustrating the Blaw collapsible steel centering for sewers, conduits, culverts, etc., for which they have acquired the patent rights in this country. The catalogue is excellently produced and illustrated.

We would mention that Messrs. Le Bas do not sell these centres, but lease them, a method which is very highly to be commended, as it obviates the contractor getting a large stock of centering on his hands which he may not use again. We understand that the price of leasing is under the cost of building timber centering.

Fawcett Construction Co., Ltd.—We have received particulars of a new form of girder construction, entitled Mon'lithcrete, which may be briefly described as lattice girders with the compression web members omitted, and the top flanges reduced to two-thirds the sectional area of the bottom flanges, it being found by experiment that this metal is superfluous when used in combination with concrete, which takes up the compression. The effect of this construction is, the concrete passing through the web becomes monolithic, and local loads are distributed over a wide area, and the concrete is also so held by the web bars that it cannot expand along the span of the girder, and is held in the opposite direction by twisted bars laid in the web openings, which, coming two-thirds down in the thickness, or below the axis, also act as tension bars to resist load.

Barrett Manufacturing Co. are supplying some thousands of rolls of Congo roofing to the Italian Government for use at Messina and the earthquake affected area in Sicily.

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CONTRACTS.

Coignet (Edmond), Ltd.—New Government Buildings, Jamaica; Post Office, Lombard Street, H.M. Office of Works; boiler foundations, H.M. India Office; jetty in the Camber, Portland, H.M. Admiralty; wharf, Portslade, Sussex; piling at Norwich; tank for Paper Pulp Co., West Hartlepool; floors and swimming bath to Yeadon and Guiseley schools, York; floors to shops, etc., in Boar Lane and to Messrs. Blakey's premises, Leeds; a footbridge and a coal store, Erith; additions to warehouse and business premises in Paternoster Square.

Columbian Fireproofing Co., Ltd.—New schools at Acton Wells, Gosport, Colchester, Norwich, Cwmavon, Glamorganshire; baths at Burnley; generating station at Dundee; new offices for Messrs. Nobel, Glasgow; new premises at Great Marlborough Street and Great Portland Street, London; School of Art at Liverpool; new City Hall, Perth; and banks at Luton, Vauxhall Bridge Road, Malvern Road, and Notting Hill, London.

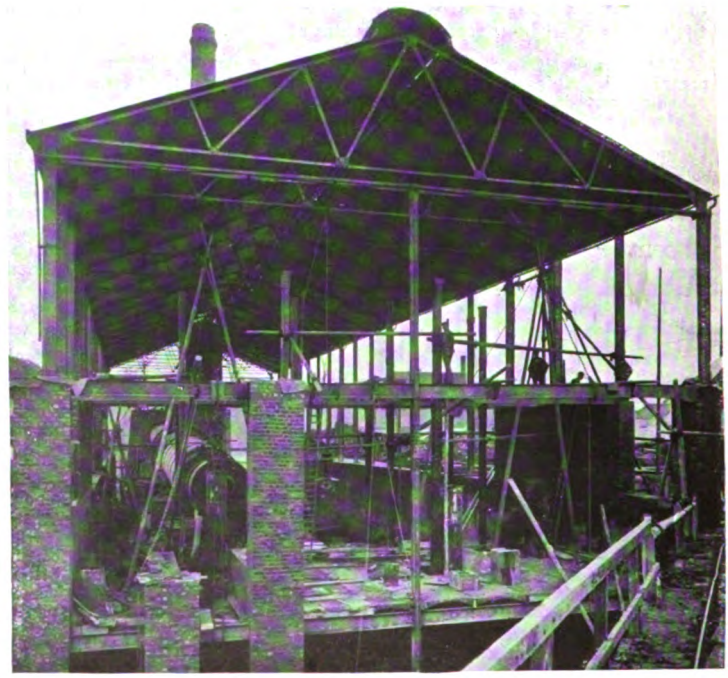
Holloway Bros. (London), Ltd.—Flat at Battersea Polytechnic; balcony at Wimbledon; strong room at Messrs. Barclay's Bank, Leadenhall Street; water tower at Roydon; roofs at Hans Crescent and over motor garage at Wandsworth.

Patent Indented Steel Bar Co., Ltd.—Glasgow main drainage works; sea defence works, Teignmouth; grain silos, South America; warehouse floors, Halifax, Bombay, Portslade, Leicester, Birmingham; reservoirs, Crampton District and Consett Waterworks; reservoir covers, Whitehaven Waterworks; South Darley Waterworks extensions; tank, Southborough; water tower, Gnosall; Hawke spinning mills, near Manchester and Shiloh mills, Lancs.; sewage works at Prescot and Dinnington; Register House, Edinburgh; rating offices, Guildhall; schools in Limerick and for the Kent Education Committee; workshops for the blind, Liverpool; Bank Buildings, Jamaica; Medway Conservancy Offices, Rochester; coal bunkers, Croydon; strong room, Belfast; laundry, Sheffield; bakery, Govan; generating station, London; Angerton Bridge; straw store, Hanley; church, Hobart, Tasmania.

Somerville, D. G. & Co.—Recent steelwork contracts completed: Roofing for Carnegie Library, Dundee; Waterworks building, Guildford; and for Messrs. Ediswan's works at Ponders End. A Sanatorium at Virginia Water; three telephone exchanges; a steel bridge for the City of Norwich

United Kingdom Fireproofing Co., Ltd.—Northern Assurance Buildings, Glasgow; Constabulary Buildings, Northallerton; schools at Southbank, Yorks; Clarence Hotel, Manchester; laundry for Salford Hospital; power stations at Horseferry Road and St. John's Wood; Eccles Hall, Drayton Park; Telephone Exchange, Lee Green; Post Office, Barnsley; business premises, Chippenham; reinforced concrete foundations, St. James's Church, New Barnet; and other smaller contracts.

Steel Construction at Denham.—An interesting example of structural steelwork has just been completed at Haresfield, Denham, where a new rotary kiln house has just been constructed by Messrs. D. G. Somerville & Co., of New Cross and Westminster, for Messrs. Coles, Shadbolt & Co., Ltd.



The building is chiefly remarkable for the great height and extent of the superstructure, which, as shown in the illustration, is some 200 ft. long by 50 ft. wide, and consists of steel stanchions 40 ft. in height, rigidly braced together, supporting the steel roof principals. The covering consists of corrugated galvanised iron, secured to angle iron purlins. The interior construction consists of several floors carrying the various machinery, steel stanchions supporting the heavy girders.

The whole of the constructional steelwork was turned out at Messrs. Somerville's works at Archangel Wharf, New Cross.

We regret that want of space prevents our showing plans and sections of the interesting steelwork.

The work was carried out most expeditiously, the whole time occupied, including the erection, being no more than seven weeks.

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume IV. No. 2. LONDON, MAY, 1909.

EDITORIAL NOTES.

THE NAVY AND THE LACK OF DOCKS.

THE debates on naval matters that have recently occupied the time of the House of Commons have in the main been devoted to the shipbuilding programme.

The question of dock accommodation has, as heretofore, been almost entirely neglected.

We have previously referred to the lack of dock accommodation for meeting the growing number of monster warships.

The position in this respect will by 1912 be far more serious than we desire to describe in detail in these columns.

It should be remembered that a dock to hold a Dreadnought takes from five to six years to construct, and that its construction cannot be materially accelerated.

The average cost of such a dock may be taken at only £250,000.

We would point to the absolute necessity of additional docks being commenced at once, so that there may at the earliest moment (probably 1914 or 1915) be at least three such full-sized docks at Rosyth, three more on our East Coast, and two more on our South Coast beyond those already in hand—*i.e.*, eight more docks at the additional cost of £2,000,000 spread over five years. Eight such docks can practically be obtained for the same money as one Dreadnought, and yet without them the value of the majority of our future battleships will be substantially discounted. The docks will be urgently wanted long before the dates at which they can be completed, even if started forthwith, for the number of heavy battleships put in hand before 1912 will certainly be far larger than which any member has so far stated in the House of Commons, and any such temporary expedient as floating docks would be far too costly and unpractical.

The lack of proper dock accommodation is most serious on general grounds, but the technical fact of the time that such docks require for construction makes the matter one of great national urgency.

THE INSTITUTION OF CIVIL ENGINEERS AND REINFORCED CONCRETE.

IN our issue of March last we drew attention to the Committee on Reinforced Concrete which had been formed by the Council of the Institution of Civil Engineers, and we indicated the advisability of any research work to be undertaken by that Committee having the co-operation of those bodies that had already given considerable attention to the subject.

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It has come to our knowledge that several of the other technical bodies concerned in the subject have been in touch with the Institution of Civil Engineers on the question of co-operation, but that unfortunately the "powers that be" at Great George Street have intimated their intention to move entirely on their own for the present. The "splendid" isolation of the Council, which is so unfavourably commented upon by the technical professions generally, is to be continued, and we assume that, as was the case some three years back when reinforced concrete received the cold shoulder in Great George Street, only to be very ably dealt with by the Royal Institute of British Architects, so again the Great George Street leaders will find that other bodies will do the truly practical work for the professions they represent, whilst the governing body of the Institution of Civil Engineers will probably theorise in a dignified but by no means popular or useful manner.

We also learn from an authoritative source that the Institution proposes approaching the National Physical Laboratory to undertake a certain series of tests. It is to be hoped that the Laboratory Committee at Kew will be very careful to sound the other bodies concerned if the proposed research work meets general scientific and practical requirements. To meet the wishes of any one society, even if it happens to be a subscriber, would be unwise, and would probably lead to some move again being made in the House of Commons, as had to be made on a recent occasion when the Laboratory was stated to be taking a somewhat one-sided view of its functions. Research in reinforced concrete affects the architect, surveyor, fire surveyor, the builder and contractor quite as much as the civil engineer, and if the Institution of Civil Engineers chooses to work in splendid isolation it is answerable only to its members; but the Physical Laboratory enjoys a substantial grant out of public funds, and thus any work done under its auspices should meet, as far as possible, the requirements and views of all the various bodies concerned.

Any blundering would be regrettable, both in the interests of the subject and of the Laboratory.

PAPERS ON CONCRETE AND REINFORCED CONCRETE.

It is with satisfaction that we note the increasing number of papers that have been recently read on concrete and the usefulness of reinforced concrete in particular. The rays of publicity that are thus focussed upon the subject are to be welcomed from every point of view, and the facts presented in those papers which we chronicle from time to time prove conclusively that reinforced concrete is becoming a popular building material, and that its prospects of universal adoption seem to increase from day to day. The present age of hurry does not always look with a favourable eye upon the reading of papers, and many of them are characterised as nugatory. We, however, hold that such is not the case with the papers and discussions that relate to the uses of reinforced concrete—with few exceptions they have had their uses. The information and instruction thereby obtained must be invaluable and cannot be overestimated, whilst the advantages that accrue from an unrestricted discussion—both *pro* and *con*—which generally follows the reading of papers must be great.

Under the heading of "Memoranda," quite a number of the papers recently presented are recorded, and the exigencies of space alone prevent our giving

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more extensive summaries. The subject matter extends from concrete and reinforced concrete to aggregates and Portland cement—*i.e.*, the constituents. Further, we refer to a paper presented on the corrosion of steel in concrete in these editorials, and to a notable paper on concrete arches in our article dealing with the work of the Concrete Institute.

There are those who maintain that it is possible to have too much of a good thing. So be it, but even a good thing taken in overdoses must eventually bring about an effective result. Thus, if by continual lectures the Local Government Board were eventually impressed with the urgent need that exists for formally altering its attitude in differentiating in its loan periods so adversely against reinforced concrete, as it still does to-day, then we say, unhesitatingly, the more lectures we have the better. We should, however, already be content if the Board instituted a departmental inquiry into the subject as a step towards regulating its procedure.

REINFORCED CONCRETE AT EXHIBITIONS.

JUST as the subject of reinforced concrete has been particularly conspicuous in lectures of late, so is there a greater tendency than hitherto to demonstrate the usefulness of this material at exhibitions.

We notice with much interest that quite a number of the exhibits at the Building Trades Exhibition embodied examples of reinforced concrete work, and we now hear that it is proposed in the building construction section of the Shepherd's Bush Exhibition to have some space devoted specifically to reinforced concrete.

Anything that can be done to popularise reinforced concrete by exhibition should be welcome, as it is only by popularisation that full use will be able to be made of this economical and practical form of construction.

STEEL CORROSION IN CONCRETE.

BEFORE the members of the Society of Engineers at their meeting on April 5th, held at the Royal United Service Institution, Mr. Ernest R. Matthews, A.M.Inst.C.E., read a paper on "The Corrosion of Steel Reinforcement in Concrete." Mr. Matthews stated that many well-known engineers avoided using reinforced concrete, believing that the metal corroded, and, being covered by the concrete, it was difficult to ascertain the extent of any corrosion. He had experimented with 20 concrete blocks, none of which were specially prepared. The metal inserted varied; in some cases it was rusty, and in others it was quite clean. The results led to the following conclusions:—

(1) That rusty steel embedded in concrete will in a very short time become bright, regardless of whether the concrete is in water or air. This point has, in the author's opinion, been conclusively proved by his experiments. (2) That the application of cement grout to steel is an effectual safeguard against corrosion, but that the greatest care should be taken in the grouting process to see that every portion of the steel is well coated, and that before the steel is embedded in the concrete the cement grout is allowed to become quite dry upon the steel. (3) That if the aggregate used for the concrete is not porous, and the concrete is well mixed, the reinforcement being well embedded, no cement coating is needed. (Seeing that the application of a coat of cement grout is such an inexpensive procedure the author makes it a rule in carrying out work of this kind to have all reinforcement coated in this manner.) (4) That no porous materials, such as coke breeze or slag, should be used in connection with reinforced concrete work, if such concrete is intended to be under water or exposed to the air. (5) That linseed oil or turps or probably any other coating except cement or lime applied to steel before its insertion in concrete facilitates rather than prevents the rusting of the metal. (6) That it is of great importance to see that the reinforcing steel is well embedded in the concrete, so that

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every portion of it is covered with cement. (7) That the best results were obtained when the aggregate consisted chiefly of broken stone or brick bats. Gravel would no doubt answer as well. (The author was surprised that such a good result was obtained with an aggregate composed of brick bats.) (8) That river sand, generally speaking, is not satisfactory for reinforced concrete work, where such work is required to be watertight.

Mr. Matthews is to be congratulated upon undertaking experimental work, and we feel convinced that if he would concentrate his efforts in this direction, taking up some specific problem such as corrosion, rather than covering too wide a range of investigation, his efforts will be much appreciated by those interested in concrete.

REINFORCED CONCRETE IN EARTHQUAKE ZONES.

Now that the facts regarding the earthquake on the Straits of Messina have reached this country, and the results of this terrible catastrophe can be examined from the technical aspect, the student of building construction must soon realise the entire unsuitability of the structures that have been so very generally used up to the present in many districts subject to earthquake shock.

There can be no doubt that either the very lightest form of wood construction should be applied, as in Japan, or, if permanence and architectural effect are desired, some form of monolithic construction should be applied, as is obtainable in reinforced concrete. Masonry and brickwork are entirely out of place, and even steel frame covered with concrete does not appear to have the same advantages as reinforced concrete in its simplest form. In fact, we are under the impression that a serious error has been made at San Francisco and elsewhere, in adopting too freely steel frame construction, where reinforced concrete would have been more suitable and probably also less expensive.

What has been done in San Francisco in the direction of reinforced concrete structures, on the other hand, merits careful consideration, as does also much of what is being taken in hand at Kingston (Jamaica) and at Valparaiso.

In our January issue we presented an illustration of some public buildings about to be erected in reinforced concrete in Jamaica, and in an earlier number we illustrated some of the reinforced concrete structures which were being put up in California. From these examples it will be seen that there is not the slightest danger of such structures becoming eyesores, as is frequently argued by an older generation of architects. The design and architectural supervision must obviously be placed in the hands of men who are really good designers, for, no matter what material be entrusted to his hands for shaping, a bad designer will create eyesores for his fellow-citizens. To condemn the artistic possibilities of reinforced concrete simply because some of the buildings in this material have unfortunately occasionally had architects of poor ability, or no architects at all, is unfair. The hundreds of ugly buildings erected in the most beautiful of natural materials only too plainly speak of the importance of the personal element in all buildings of architectural pretensions. The personal element is, in fact, much greater than any question of the material used. Even cast-iron or stucco can be pleasing to the eye when dealt with by a good designer.

Thus, the only argument we have heard put forward against erecting the more important buildings in the earthquake zones in reinforced concrete should be easily disposed of; and it is to be hoped that the lessons of the great catastrophe in Sicily will be learnt throughout the civilised world.

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The New Western District Post Office

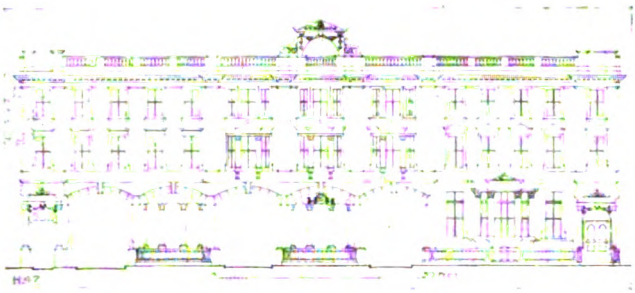

FIG. 1. THE NEW WESTERN DISTRICT POST OFFICE.

We have referred to these new buildings before, soon after they were started, but in this issue we are able to present some photographs during the construction of the reinforced concrete work. The previous article, with plan, was in our issue of July, 1908.—ED.

THIS extensive building, which is now almost completed as far as the reinforced concrete part of the work is concerned, offers another striking example of the growth of this new material in England. The building has been designed in H.M. Office of Works to the instructions and under the supervision of Sir Henry Tanner, I.S.O., and we understand that economy of cost and space and fire-resistance were the principal reasons for which reinforced concrete was adopted.

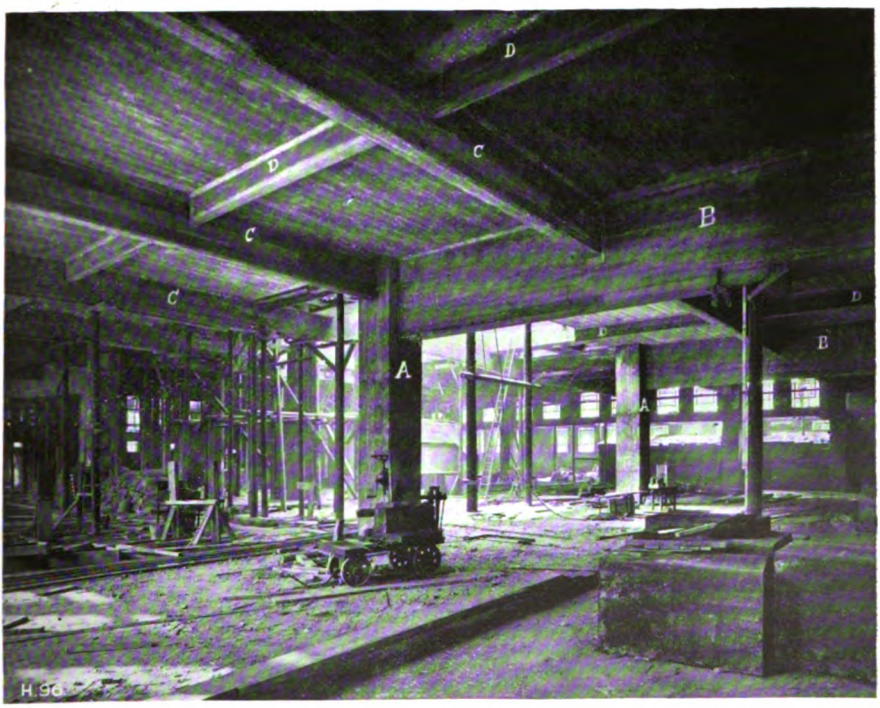

FIG. 2. THE NEW WESTERN DISTRICT POST OFFICE.
Interior view of Ground Floor.

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Fig. 3. The New Western District Post Office. Interior view of First Floor.

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The entire building, excepting the front (*Fig.* 1) in Portland stone, has been constructed on the Coignet system of reinforced concrete, and this work was obtained in competition by Messrs. W. King & Sons, contractors, of London, licensees of Messrs. Edmond Coignet, Ltd. The "Ferrocrete" Brand of Portland cement, manufactured by the Associated Portland Cement Manufacturers (1900), Ltd., has been used throughout, and the mild steel bars composing the reinforcement were supplied by Messrs. The Earl of Dudley's Roundoak Works, Ltd., Brierley Hill, Staffs.

FIG. 4. THE NEW WESTERN DISTRICT POST OFFICE.
Interior view of Second Floor.

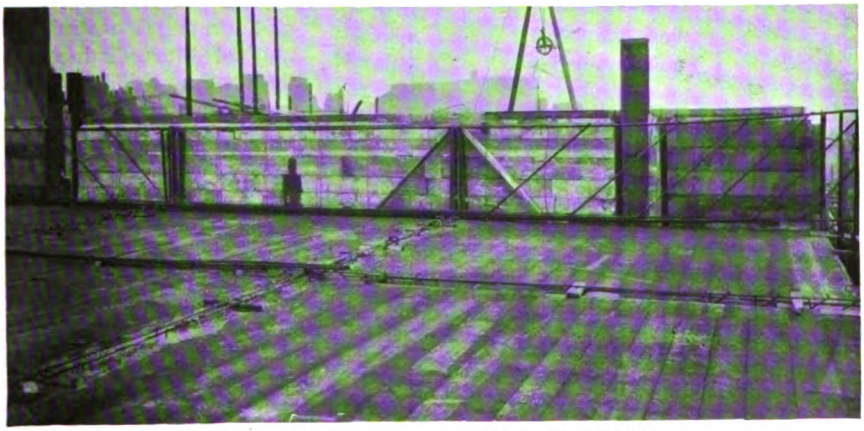

FIG. 5. THE NEW WESTERN DISTRICT POST OFFICE.
Steel reinforcement of beam in position before concreting has been commenced.

The building is situated between Cavendish Square and Wimpole Street and comprises a block of about 200 ft. frontage and 160 ft. in length, with basement, ground floor, first and second floors and flat roof. The last-named has been designed with a view to the possibility of heightening the building and using the roof as one of the floors.

A description of this building while in course of erection was given in our last July number. We are now giving photographic views taken on the ground floor, first floor and second floor, showing the arrangement of beams and pillars.

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It will be noticed that only four pillars have been provided for in the centre of the main part of the building, which is to be used for sorting offices. The spans between these pillars and the outer walls vary between 45 ft. and 39 ft. The entire building, including walls 6 in. thick, stairs, water tanks, etc., has been constructed in reinforced concrete. The superload on the ground floor and first floor is 1 cwt. per sq. ft. and $\frac{3}{4}$ cwt. on the second floor and roof.

One of the chief features of the building is that the principal beams, carrying the first floor, second floor and roof, are suspended by means of strong stirrups to beams 6 ft. high forming the internal walls surrounding the inner court. By this means it has been possible to obtain the maximum height for the windows.

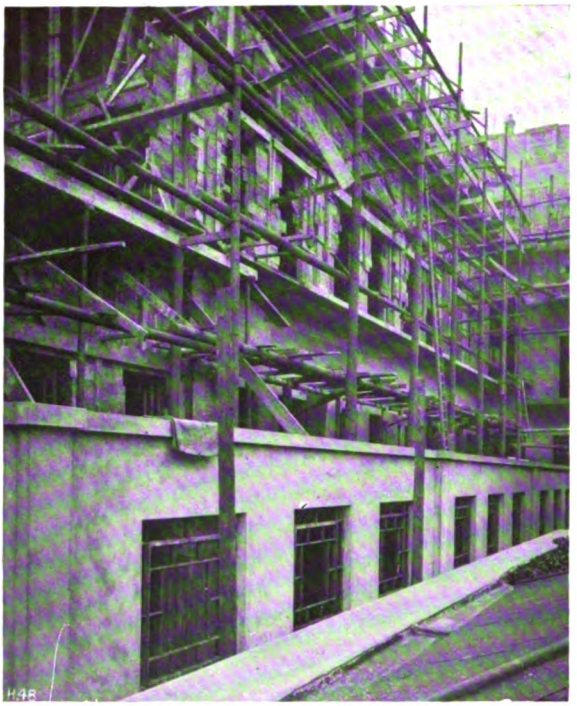

Fig. 6. The New Western District Post Office. Portion of reinforced concrete exterior wall completed and in course of construction.

Another noticeable feature is found in the extensive beams, over 12 ft. in height, which support the main beams of the principal floor. These beams are only 10 in. thick and have a series of large windows in the portion which is underneath the first floor and which is situated below the neutral axis. The span of these main beams is 45 ft.

The photograph shown in *Fig.* 2 is a view taken on the ground floor, showing the work stripped of its centering and during the testing operations on the floor above. Two of the massive central pillars marked A are distinctly seen and the scantlings of these are 34 in. by 34 in.

The height between the ground floor and first floor is 18 ft. The two principal beams, marked B, supported by these pillars measure 60 in. by 14 in., with a span of 45 ft. They support two secondary beams, C, the dimensions of which are 30 in. by 10 in., with a span of 37 ft. It will be noticed that some of the latter beams are shown extending into the inner court and apparently unsupported. These beams are suspended to an upper beam above the floor level forming the walls of the inner court. The beams marked D on the photograph have scantlings of 10 in. by 30 in. with a span of 37 ft. These beams are also supported in the same manner as above described. *Fig.* 3 is a view taken on the first floor showing the extensive area and spans without any pillars. The walls of the inner court marked E are, in reality, heavy beams 12 in. thick by 6 ft. high. The two projecting uprights contain the stirrups supporting the two principal beams underneath the floor and supporting same as described above. The beam marked F is a scantling of 14 in. by 48 in. and a span of 45 ft., supporting two secondary beams 10 in. by 24 in. The scantling of the ribs is 5 in. by 16 in. The beams marked G appear to be supported by the two panels, H, between the windows. These, however, are supported in the same manner as the corresponding beams on the principal floor, which means that they are suspended

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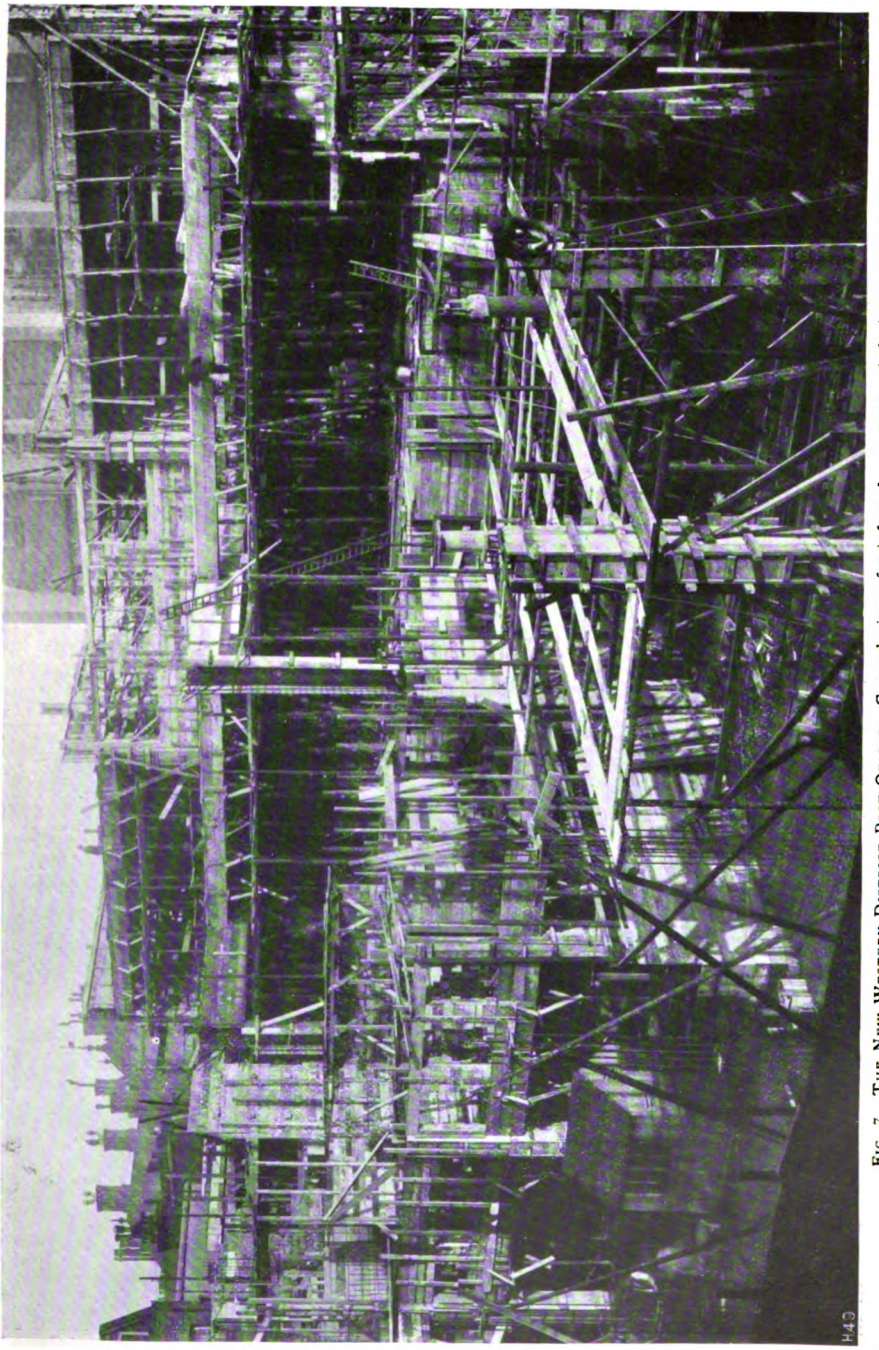

FIG. 7. THE NEW WESTERN DISTRICT POST OFFICE. General view of reinforced concrete work during construction.

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to a beam above, forming walls of the inner court. The thickness of the slab on the principal floor is $4\frac{1}{2}$ in. Several heaps of sand will be noticed on this floor, these being preparations for the testing operations by means of a thick layer of sand spread over the entire surface to be tested.

Fig. 4 is a view taken on the second floor, showing the beams underneath the roof, also the openings with trimmings above for the skylights. The same construction was applied in the case of the roof as underneath the second floor, the principal beams being also suspended to large trimmer beams surrounding the inner court, the interior of which has been rendered more light by applying white glazed tiles on the surface of the concrete.

Fig. 5 shows one of the steel frames of suspension beams surrounding the inner court. The bars are gradually bent up at an angle of 45 degrees in the manner of trusses in order to resist the shearing nearest the points of support.

This method, which is a feature of the Coignet system, is stated to be economical on account of the fact that the section of the steel in tension decreases gradually from the centre of the beam where the moments attain their maximum to the points of support where the moments attain their minimum, the bars being turned up and spaced gradually to resist the shear, which is, of course, greater at the points of support. In this manner, it is stated by the contractors, no steel is wasted. The bars are prevented from getting out of position by hooks which are bent over a straight longitudinal upper bar. The two suspended beams are held up by means of several flat iron stirrups. The meshwork of the slab is not shown in this photo.

Fig. 6 is a photograph showing one of the sides of the building with walls 6 in. thick in reinforced concrete rendered with cement and sand.

Figs. 7 and 8 are exterior views taken during the construction of the work.

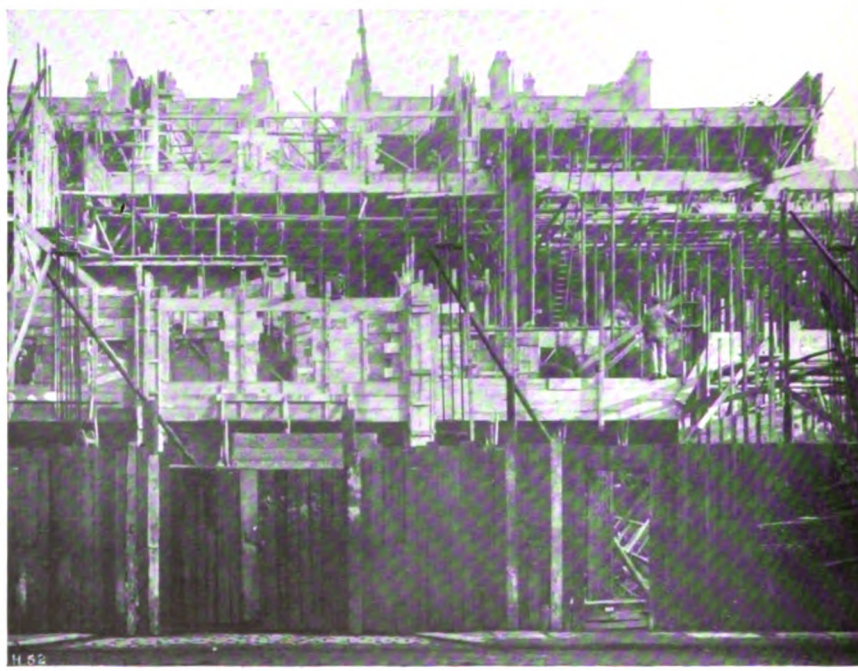

Fig. 8. The New Western District Post Office.
Exterior Wall in course of construction.

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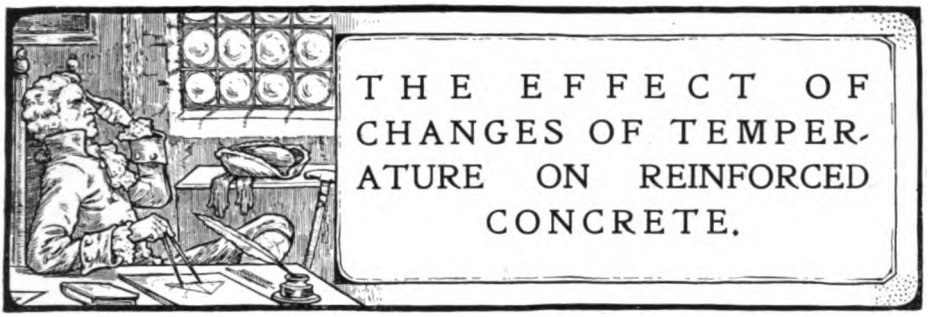

THE EFFECT OF CHANGES OF TEMPERATURE ON REINFORCED CONCRETE.

By Dr. FRITZ VON EMPERGER (Vienna).

A most valuable paper has been presented on the Effect of Changes of Temperature on Reinforced Concrete before the Vienna Society of Civil Engineers and Railway Engineers by Dr. Fritz von Emperger, the Editor of our contemporary "Beton u. Eisen," and a summary of the deductions obtained from this paper has been prepared by Mr. Cecil H. Desch, D.Sc. Ph.D.

The subject is one to which attention should not only be accorded at home, but also in our Colonies, where the climatic conditions render the question of temperature of the utmost importance.—ED.

In the Austrian Ministerial instructions for the use of reinforced concrete it was prescribed that allowance should be made for changes of temperature between —20° and +30° C. (−4° and +86° F.), assuming a coefficient of linear expansion of 0·0000135 per 1° C. (0·0000075 per 1° F.). The author has investigated the question how far such variations in the temperature of the air give rise to corresponding variations in the internal temperature of the concrete mass.

The oscillations of temperature provided for in the above instruction are certainly excessive, the mean monthly temperature of Vienna showing a difference of only 22·1° C. (39·7° F.) between January and July, and the absolute maxima and minima only differing by 44·1° C. (79·4° F.). The importance of the question is shown by the fact, quoted from the American literature, that a granite arch railway bridge is more severely stressed by a variation of temperature of 6° C. (10·8° F.) than by the passage of a railway train. In a recent case a tender had been presented for a railway bridge of 36 metres (118 ft.) span, and the enforcement of the above regulation necessitated an increase in the tender of 35 per cent., the result being that the design was abandoned, and a wooden bridge substituted.

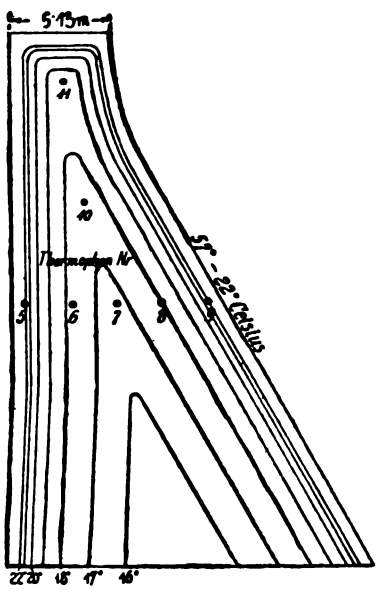

Fig. 1.

The author's experimental investigations justify the conclusion that such variations in the temperature of the air as occur are not transmitted to the interior of the concrete mass. The conditions are entirely different from those prevailing in a steel bridge, which, if exposed to the sun, may assume a higher temperature than the surrounding air. Everyday experience shows that the behaviour of masonry, etc., is quite different. That the stresses due to temperature cannot be comparable with those due to loading is seen on considering a simple case. Assuming the coefficient of

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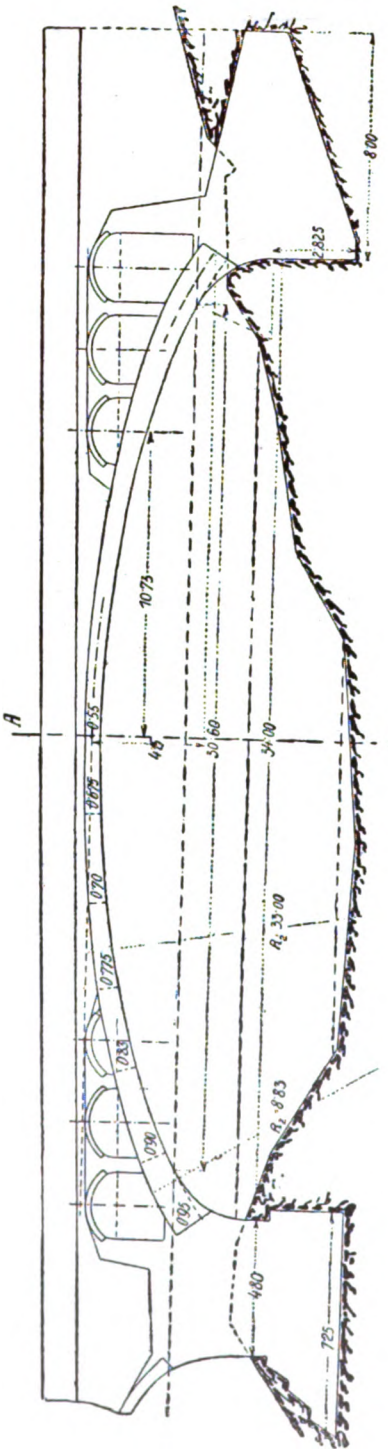

FIG. 2.

expansion of concrete given above, this indicates a stress of 1·9 kilograms per sq. cm. for 1° C. (15 lb. per sq. in. for 1° F.). Imagine a stone with the upper side exposed to sunshine and the lower side in shade, the difference in temperature between the upper and under surfaces easily attaining 20° C. (36° F.). This would mean a stress which no lintel could resist. In fire tests of concrete, a temperature of 920° C. (1656° F.) has been reached under a load of 3,000 kilograms per sq. metre (614 lb. per sq. ft.) without injury during four hours. Such facts indicate that the prescribed allowance for temperature is excessive.

In a recent competition in Stockholm for a granite bridge of three spans of 15 metres (49 ft.) each, provision for a variation of temperature of 80° C. (144° F.) was specified. The prize design was a 3-hinged arch, although the central piers were 30 metres (98 ft. 5 in.) high. The use of a hinged arch in a masonry bridge of this kind is unjustifiable, and is only explained by the unreasonable temperature requirements. In studying the influence of temperature, two cases have to be distinguished, according as the mass is exposed to variations of temperature on one or both sides. The first, occurring in arches carrying superincumbent earth, has been studied separately. It is a well-known fact that masonry at a depth of 1 metre (3′ 3″) is not subject to frost, and that ground water at a depth of only 50 cm. (20 in.) is independent of the daily variations of temperature. A reinforced concrete arch, covered in and packed with earth or other material at the abutments, may be assumed to have a practically constant temperature on one side. If the inner side has exactly the same temperature as the air, taking up all variations, then there must be a linear diminution of temperature through the section, and the whole arch experiences only *one-half* of the variation of the surface. Thus, if the variation in the air amounts, as assumed in the regulation, to 50° C. (90° F.), at a depth of 90 cm. (35½ in.), the variation certainly cannot exceed 10° C. (18° F.). The mean is 30° C. (54° F.). It is therefore quite unreasonable to assume that the mass is subject to the maximum variation.

A fine crack often appears in the side of an arch, and this opens and closes with

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changing temperature. In his first large bridge, constructed in Cincinnati in 1894, the author provided a joint at the abutment, consisting of a groove at the place at which a crack would be likely to appear. That even this precaution may be dispensed with, vault, spandrels, walls, road and abutments being made monolithic, is certain from many modern examples. Several bridges in the neighbourhood of Vienna, such, for instance, as that over the Schwechat, constructed by Messrs. Ast & Co., have proved perfectly satisfactory, in spite of the absence of provision against change of temperature. There are undoubtedly many cases in which bridges have developed tension cracks, not owing to temperature changes, but to faulty dimensioning. As soon as rupture has taken place, the arch may be considered as being composed of separate sections, in each of which the temperature effect is concentrated, whilst it is essential to a good arch that temperature effects should be distributed over the whole structure.

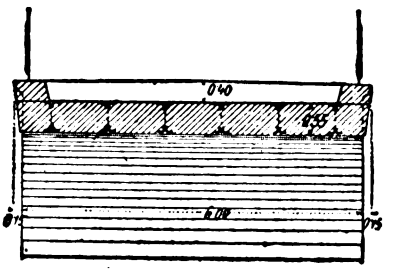

FIG. 3.

Passing now to the case in which the structure is exposed on both sides to variations of temperature, the question of thermal conductivity becomes of importance in two cases, chimneys and valley-dams. The first of these, the construction of reinforced concrete chimneys has reached a high development in North America. The mode of provision by reinforcement for stresses due to heat are explained in Vol. III., part 3, of the "Handbuch für Eisenbeton." The assumption is made, according to Prof. Seliger, that the temperature falls from that of the inner to that of the outer surface in a linear manner. No exact measurements exist, but there is no reason for rejecting this distribution of temperature, although many have thought that the whole mass must have the temperature of the inside of the chimney. It is perhaps such an idea, suggests the author, that has restricted the construction of reinforced concrete chimneys in Europe. A year ago, however, 400 such chimneys had been erected in North America, only eight of which have been failures.

A few measurements were made during the re-concreting of the Idria bridge by Mr. Schell. The day temperature in sunshine was 0° C (32° F.), at night −8° to −10° (18° to 14° F.), but a thermometer inserted in the concrete showed an almost constant temperature. Although this was no doubt due in part to the heat developed by the cement in setting, still the results show that the external variations had very little effect on the internal temperature of the concrete mass.

The only direct measurements of temperature at different points in the interior of a mass are those conducted during the building of valley dams, mainly in America. The most extensive series of such measurements was made at the Bonton dam in New Jersey. Spirals of wire were inserted at various depths, and the temperature determined from observations of thei relectrical conductivity. The series is incomplete, since it extended only over the period of construction, but the results show sufficiently that the increased temperature due to setting is only slowly lost in the interior of the dam, several years being necessary for the elimination of this factor. Mr. Merriman has concluded from the results of these experiments that when the constant state is reached the temperature varies as the cube root of the distance below the surface of the concrete. *Fig.* 1 shows the isotherms constructed on this assumption. At a depth of 60 to 75 cm. (2 ft. to 2 ft. 6 in.) the variations amount to 16-20° C. (29-36° F.).

The theory on which calculations are to be based requires somewhat careful

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examination. As regards arches, the conditions may evidently vary between those of a semicircular arch and of a straight girder. Imagine a girder so fixed that the span is invariable. A rise to +30° C. (86° F.) causes a compressive stress of 47 kg./cm² (668 lb. per sq. in.), and a fall to —20° C. (—4° F.) a tensile stress of 38 kg./cm.² (540 lb. per sq. in). Both these stresses exceed the permissible limit, and the only possible conclusion is that the assumption of an unalterable span is unjustifiable, since the rigid application of the above conclusion would make the construction of a girder bridge impossible. For instance, a bridge of 60 metres span (197 ft.) would, with a variation of temperature of ±13° C. (±23° F.) cause a displacement of each of the abutments by 50 mm. (2 in.). If we assume the displacement to be zero, the horizontal thrust or pull will amount to 90 tons. The author's experiments, and those of S. A. Spitzer in 1896, however, indicate that the abutments are not immovable, but that they yield under the stresses applied.

The author's own experiments have been made with arched bridges, the daily temperature and the movements of the crown being measured. The first of them refer to a Melan bridge over the Elbe at Döberney, constructed by Messrs. Pittel & Brausewetter (*Figs.* 2 and 3, dimensions in metres). The steel girders are only 4 cm. (1·6 in.) below the surface of the concrete, and the effect of temperature is therefore more marked than usual. A calculation of the deformation produced by changing temperature, assuming immovable abutments, indicates a vertical displacement of the crown, in millimetres: $\triangle f = 1{\cdot}045t$

where t is the variation of temperature. Assuming, on the other hand, perfect yielding of the abutments $\triangle f' = 0{\cdot}0527t$

The curves representing the observations indicate considerable yielding of the abutments, and also show that only one-half of the variation of temperature affects the interior, even of such a thin structure as this. A few data are also available from the domed roof of a reservoir at Krasno, in Bosnia, constructed by Messrs. Janesch & Schnell. Unfortunately, measurements were only made on the two days following the removal of the centering. Curves for this short period are given by the author.

CONCLUSIONS.

The following conclusions seem to follow from the facts collected:—

(1) The variations of temperature named in the regulations can apply only to atmospheric temperatures, and require correction for other places and climates.

(2) Atmospheric temperatures are only attained by structures consisting of steel only, or in which steel is actually exposed.

(3) In concrete or reinforced concrete structures, the depth to which changes of temperature have to penetrate has to be taken into account, and an arithmetical mean taken for calculation. The duration of any maximum in the external temperature must also be considered. Failing decisive experiments, it may be assumed that the temperature range at a depth of 60 cm. (2 ft.) below the surface is only one-half of that outside, and at a depth of 1 metre (3 ft. 3 in.) only one-quarter. This assumption is probably on the safe side. When these actual temperatures are employed, however, the permissible stresses must be increased, as the same factor of safety should not be used for stresses due to temperature as for those due to load. If this plan is not followed, the range of temperature assumed should be lessened. In connection with the Swiss regulations, Maillard has proposed that the limits should be + 15° and — 20° C. (59° and — 4° F.), and that the permissible stresses employed in the calculation should be increased by 50 per cent. This is a reasonable proposal, the effects of which would be to bring the provision for variation of temperature within limits which are practicable and economical.

The facts mentioned in this paper show clearly how many preconceptions based on experience with other materials have to be abandoned when dealing with reinforced concrete. Practice in this mode of construction is necessarily based on certain fundamental assumptions, the number of which is steadily diminishing. The question treated here is one of those in which the necessity of replacing mere prejudice by a scientifically grounded theory is most obvious.

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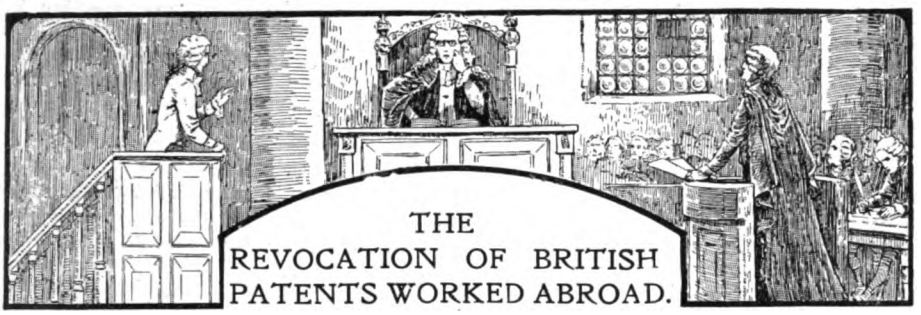

THE REVOCATION OF BRITISH PATENTS WORKED ABROAD.

By DOUGLAS LEECHMAN, A.Inst.M.E.
Barrister-at-Law.

The recent decision on the revocation of British Patents worked abroad is of far-reaching importance to those concerned in concrete and reinforced concrete, and we are thus presenting a summary of the first case decided on the subject.—ED.

The result of two Patent actions against Coignet and others relating to asbestos and cement slabs was briefly referred to in CONCRETE of January last. The revocation took place under Section 27 of the new Patents and Designs Act, the principal sub-sections of which run as follows :—

(1) At any time not less than four years after the date of a patent, and not less than one year after the passing of this Act, any person may apply to the Comptroller for the revocation of the patent on the ground that the patented article or process is manufactured or carried on exclusively or mainly outside the United Kingdom.

(2) The Comptroller shall consider the application, and if after inquiry he is satisfied that the allegations contained therein are correct, then, subject to the provisions of this section, and unless the patentee proves that the patented article or process is manufactured or carried on to an adequate extent in the United Kingdom, or gives satisfactory reasons why the article or process is not so manufactured or carried on, the Comptroller may make an order revoking the patent, either—

(*a*) Forthwith ; or

(*b*) After such reasonable interval as may be specified in the order, unless in the meantime it is shown to his satisfaction that the patented article or process is manufactured or carried on within the United Kingdom to an adequate extent.

Provided that no such order shall be made which is at variance with any treaty, convention arrangement or engagement with any foreign country or British possession.

The Patents in question were Nos. 6455 and 22139, both taken out in 1900 by L. Hatschek, an Austrian. Hatschek had corresponding patents in Germany, Austria, France, and Belgium, and in 1906 granted an exclusive licence under his British Patents to a Belgian company, who sent part of their product to this country. The patented process consisted in mixing asbestos or other fibrous material with an adhesive substance, preferably Portland Cement, to form thin imitation stone slabs or tiles. The applications for revocation were filed by C. W. Zerenner, who for some time acted as agent for the tiles in this country. The patentee and the Belgian company admitted that the patented process was carried on exclusively outside the United Kingdom, but contended that they had spent all their available capital in erecting the Belgian factory, which was able to, and did, turn out all the tiles required by this country; and that it was cheaper to manufacture in Belgium owing to cheaper labour.

This was the first case of the kind decided by the Comptroller, and very great importance attached to the Appeal to the High Court, because that is the only, and therefore the final, appeal provided by the Act, and because the decision in the first case would set a precedent affecting the whole future interpretation of the Section.

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The appeal was heard by Mr. Justice Parker on March 4th and 5th, but he reserved his judgment until he had heard the arguments in the next case of the kind—the Welsbach Arc Lamp case, which came before him in the following week. In this latter case he gave leave to file further evidence, and this would involve further argument. However, his lordship gave his decision in the Hatschek case on March 26th to the following effect:

JUDGMENT.

The object of Section 27 was to prevent letters patent for monopolies (which were contrary to the spirit of the common law as being restraints on trade, and only permitted for the encouragement of inventions useful in trade) being used to prevent the development of new industries or to fetter existing industries in this country, or favour the development of industries abroad at the expense of industries in the United Kingdom.

Anyone, whether a British or a foreign subject, and whatever his motive, could, by satisfying the Comptroller of the existence of the circumstances contemplated in Sub-Section 1, impose on a patentee the onus of proving that his patent was worked to an adequate extent within the United Kingdom, or of giving a satisfactory reason why it was not so worked.

As to what constituted working "exclusively or mainly outside the United Kingdom," there was no difficulty about "exclusively," but there was about "mainly." His lordship did not think it could refer to cases where the manufacture of the patented articles in the United Kingdom was merely less than half the manufacture of the whole world. If the patented article be manufactured in the United Kingdom to as great an extent as could reasonably be expected, having regard to the development of other countries, no presumption against the patentee could fairly arise.

The use of the word "patented" in the expression, "patented article or process," did not have the effect of confining the comparison to the number of foreign-made articles imported into, and the number of such articles made in, this country.

The Sub-Section instituted a comparison between the extent to which the article or process, the subject of the patent, was manufactured or carried on in this country, and the extent to which it was manufactured or carried on abroad, whether the articles so manufactured or resulting from the process so carried on abroad were or were not imported into this country.

Nor did the Sub-Section confine the comparison to what was being done abroad and at home respectively by the patentees, his licensees and agents; what was done by others being left out of account. The section was meant to hit any abuse of the monopoly the object or result of which was to benefit foreigners at the expense of the traders within the United Kingdom.

Sub-Section 2 left to the Comptroller, subject to an appeal to the Court, to determine in each case, and having regard to all the circumstances, whether the extent to which the article or process was manufactured or carried on was "adequate," and, if not, whether the reasons put forward were "satisfactory."

Although his lordship would not define the meanings of "adequate" and "satisfactory," he did not think the working here would be adequate if it be less than it would have been but for the fact that the patentee had exercised his patent rights to the hurt of British industry, *e.g.*, that he had given foreign traders a preference over British.

Similarly, no reasons could be satisfactory which did not account for the inadequacy of the extent to which the patent was worked in this country by causes operating irrespective of any abuse of the monopoly granted by the patent.

The first thing for the patentee to do was, by full disclosure of the manner in which he had exercised his patent rights, to free himself from all suspicion of having done anything to hamper the industry of the United Kingdom. Once he had satisfied the Comptroller of this he would have gone a long way towards establishing his case, and even if he could not prove adequacy he ought to be able to show satisfactory reasons for inadequacy. This construction of the Act was in accordance with the International Convention as to revocation for non-working.

A patentee ought not to give foreigners preferential terms, nor ought he to use the period prescribed by Sub-Section 1 in developing foreign, as opposed to British.

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industries. He must at least take the same pains to develop the new industry here as he did abroad.

The demand in this country might sometimes be made up partly of a demand for the article as made abroad, because, *e.g.*, it was got up more to the taste of a section of the public, but the manufacture here could not on that account alone be said to be inadequate.

If the manufacture here was insufficient to meet the demand for the home-made article, it might well be held to be inadequate, and so it might be if there were no demand at all, because the rights of the patentee might have been so exercised as to preclude the growth of a demand, by the imposition of unreasonable prices or terms for licences, or neglect of this country in developing a foreign trade.

The fact that persons carrying on an industry in this country would make smaller profits than those carrying it on abroad would not be a satisfactory reason. Nor would it be sufficient for a patentee to prove that he could not now start an industry with any chance of profit. The question was, Could he have done so if he had used his monopoly fairly as between home and foreign trade, or if he had devoted as much time and money to developing a home industry as he had to a foreign one?

The section was not confined to cases where revocation would lead to the establishment of a new industry or the further development of an existing one in this country. Nor are patentees who obtained their patents before the Act in a better position than those who obtained them after because of the former's vested interests. But the Comptroller might possibly accept as satisfactory from the former reasons for not working in this country which he would not accept from the latter. But if a patentee had before the Act precluded himself by contract from working his patent in this country, that is not a satisfactory reason. This was in accordance with the Statute of Monopolies, and the form of Letters Patent had always contained a proviso that if at any time during the term it should be made to appear to the King or the Privy Council that the grant was prejudicial or inconvenient to the King's subjects the Letters Patent should be void.

After commenting unfavourably on the rules of procedure dealing with this Section 27, his lordship turned to the facts of the particular case, and expressed the opinion that a new industry might have arisen in this country but for the manner in which the patentee had exercised his rights, but it was quite enough to say there was no evidence to the contrary. Nor had anything been proved as to the economic impossibility of such an industry having grown up in the United Kingdom if no preference had been conferred on foreigners. There was no satisfactory evidence that the demand here would not have been much greater than it was but for the way in which the patentee had used his monopoly. The patentee had granted a licence which would have rendered his patent liable to revocation under the Act of 1902, and there was therefore no reason why he should be entitled to any indulgence. The advertisements and circulars expressing a willingness to sell the patent or enter into working arrangements had been issued at the last moment; but even if done forthwith after the Act, the fact that no one was willing to buy or take a licence to manufacture here would not have proved much.

Under all the circumstances, he thought the revocation of the patent was amply justified, and that the refusal of the Comptroller to suspend the revocation was also right.

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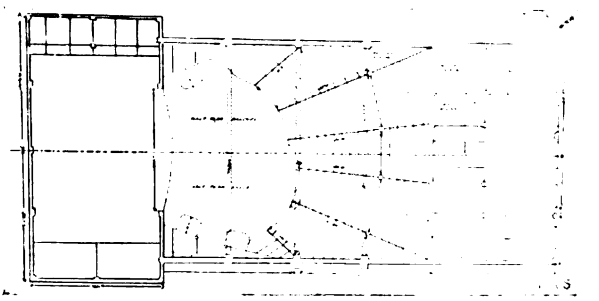
Reinforced Concrete Theatre in Los Angeles, California.



The use of reinforced concrete for theatre construction is still exceptional, and examples to be found in Europe are but few. The reinforced concrete theatre which has been erected in Los Angeles will thus be of particular interest to our readers, it being constructed to specially withstand both fire and earthquake shock.—ED.

BUILT entirely of reinforced concrete, the newly erected Majestic Theatre in Los Angeles, California, possesses some unique engineering features. The building consists of an eight storey and basement office front, with the upper three storeys extending back to over the auditorium of the theatre portion. It is this last feature that makes the building unusual.

DESCRIPTION.

The foyer is approached through a wide entrance hall, and is vaulted and groined, extending the width of the building. The staircases lead up to the balcony at either end, and entrance is had directly to the main auditorium from the foyer. A wide vestibule, together with the various retiring rooms, are beneath the staircases. This wide vestibule gives access to a smaller one, from which entrance to the Rathskeller and bar are had. These latter, as well as the kitchen, are under the office portion of the structure, thus enabling the tenants of the building to use the café during the day and permitting patrons of the theatre to sup without leaving the building.

The site measures 80 ft. by 163 ft., the office front and auditorium are 68 ft. wide, while the stage covers the entire width of the site. This arrangement leaves a passage 6 ft. wide on each side of the auditorium, which extends to the street front. Entrance to the stage can be had on either side by way of these passages, and the stairways to the gallery lead off them and have no connection whatever with the building, except through the gallery, there being an emergency exit at the rear to the fourth floor of the office front. There are two exits on each side from the main floor into these passages and the fire escapes, iron stairways (two on each side), of both the balcony and gallery also lead down into them. All these exits have separate stairways to the ground. Such in general is the plan of the building.

Detailing some of the more important engineering features of the structure attention is directed to the construction of both the balcony and gallery. Although balconies have been constructed before of reinforced concrete along similar lines we believe there are none with the great projection of both the balcony and gallery in this building. The longest cantilevers of the gallery and balcony of this structure are 27 ft. and 30 ft. projection respectively, that is, both of them have the greatest projection of any known reinforced concrete cantilever, while that of the balcony has an equal projection with the longest known steel cantilevers of similar construction. These statements, of course, do not include bridge construction.

The balcony is supported by six reinforced concrete cantilevers, giving it a free overhang of 30 ft. The two side cantilevers are brackets 18 ft. long, coming off the truss columns on either side of the auditorium. The four great central cantilevers, two of which are 45 ft. long, and two 51 ft. long, have a clear projection of 29 and 30 ft.

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respectively, and are supported on independent columns, which are located in the curtain wall, between the main floor of the auditorium and the foyer. The cantilevers rest on these columns, extend back over the foyer and are anchored in the reinforced concrete wall six storeys high at the rear of the auditorium. These cantilevers vary in section from 10 in. wide by 12 in. deep at the outer end to 18 in. wide by 78 in. deep at the maximum section over the column support, and are reinforced with seven $1\frac{3}{8}$ in. sq. twisted steel bars on the tension side, which extend through the anchor-arm into the rear wall. There are three 1 in. sq. twisted bars on the compression side. It will be seen from the drawings that as the bending moment decreases and there is a corresponding excess of steel on the tension side the bars are bent down and hooked under the compression steel. This method of disposing of the tension steel assisted the stirrups in binding the two groups of steel together, at the same time resisting so-called shearing stresses (tension on the 45 degs. plane) directly in an admirable manner. That portion of the balcony between the cantilever is constructed similar to the ordinary joist system. The risers are reinforced concrete joists or beams, resting on the cantilevers and monolithic with them, while the slab is supported on the top of one riser and hung from the bottom of the next.

This construction is very economical in reinforced concrete, for, unlike other materials, these beams are cast to conform to the curve of the balcony seats, a feature that could not be carried out in structural steel, except at a considerable increase in cost. The gallery is constructed in the same manner, but of 3 ft. less projection, having an extreme overhang of 27 ft. The column supports centre on, and are continuous with, those of the balcony beneath. Both the balcony and gallery were designed to sustain a superimposed load of 125 lbs. per sq. ft., and have been tested to over double that load. In making these tests the cantilever arm only was loaded, no load being placed on the anchor arm. This was of the worst possible condition and made the tests extremely severe ones. A superimposed load of 95,600 lbs., a little over 260 lbs. per sq. ft., was placed on one panel in the balcony between two cantilevers, and extending from the supporting columns to the front rail, an area of 361 sq. ft. This was a severe test on the floor construction, and was more than equivalent to the load for which the cantilevers were designed, and is over $2\frac{1}{2}$ times the maximum load they will ever be expected to sustain. Under the above load the deflection at the end of the 30 ft. cantilevers was only $\frac{1}{4}$ in. On the gallery a load of 84,700 lbs., slightly over 270 lbs. per sq. ft., was paced directly over one cantilever, extending from centre to centre of adjoined panels, and, as before, from the column supports to the front rail of the gallery, an area of 311 sq. ft. The deflection at the end of the cantilever 26 ft. long was only $\frac{3}{16}$ in. Allowing 150 lbs. for the average weight per person of an audience, of 50 lbs. for the weight of the opera chair and accessories, and we have a total of 200 lbs. The space allowed to an opera chair is 3·75 sq. ft., exclusive of aisles. This gives a maximum possible load of 50 lbs. per sq. ft. with every chair filled, and making no deductions for aisles. On either side of the proscenium arch, which is also of reinforced concrete, are the boxes in two tiers, and no two boxes are on the same level, but are so arranged that the top of the rail of the farthest box is on a level with the head of the occupants of the box nearer the stage. These boxes project from the wall 6 ft., and are carried by a 6 in. cantilever slab.

It is interesting to note that the complicated structure around the boxes, consisting not only of the boxes and rails at different levels, but also partition walls, several flights of stairs, and the main walls of the building, were all cast at the same time.

The spanning of the auditorium with three great reinforced concrete trusses was a bold, but successful, engineering problem. Two views of these trusses are given, one showing the arrangement of the steel reinforcement, the other the completed trusses after casting the concrete. These trusses have horizontal chords and carry a three-storey building on them. They are 71 ft. long over all, 10 ft. deep, 24 in. wide at top, 18 in. wide at the bottom, and are calculated to support a live and dead load of over 750,000 lbs. They are reinforced in the top chord with twelve $1\frac{3}{4}$ in. sq. twisted steel bars, while there are 15 $1\frac{5}{8}$ in. sq. twisted steel bars in the bottom chord. The top bars are bent down and used as shear bars, near the supports passing to and down the outside of the supporting columns, forming and giving a strong portal action. The lower bars are brought up as required in successive stages to the top

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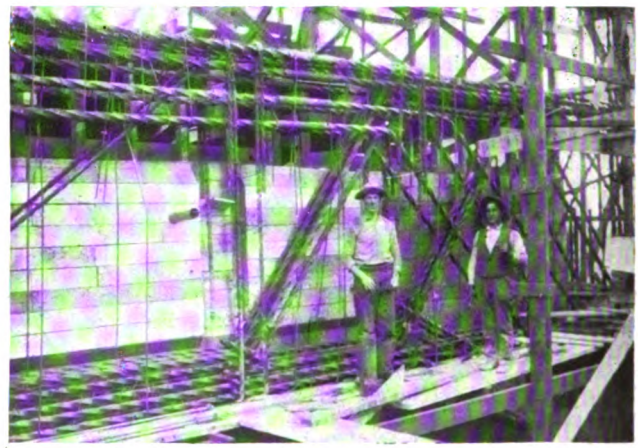
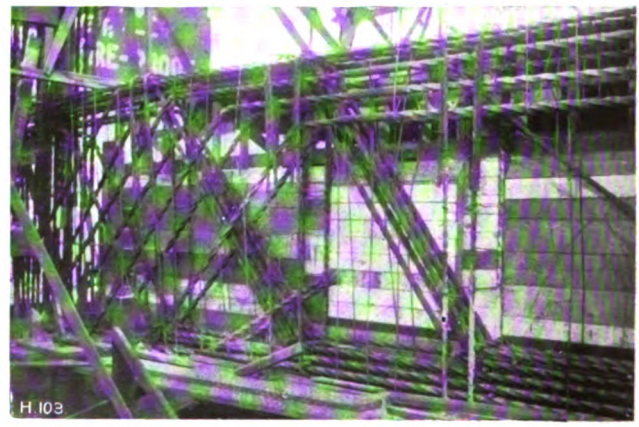
of the truss to care for the reversed stresses that occur at the supports in reinforced concrete work.

Owing to the great span it was deemed necessary to use splices, and these were located at points of least stress, and of from 5 to 6 ft. lap, with three clamps each, even then steel 50 and 54 ft. long was required. It will be seen by references to the drawings that in the corbels, where there would be maximum compression owing to the reversal of stress as above, that the steel is arranged and laced in column form, following the line of the corbel. For the purpose of reducing the dead weight the central panels were reduced in thickness to 12 in. These trusses could have been designed and built with open panels, but the centering and difficulty of properly filling the separate members would cost more than the extra concrete used. Moreover, the solid web assisted in caring for shearing stresses. The centering was not removed until the expiration of six weeks. Before striking the centering a level was set on each truss in succession to observe any deflection that might occur. Despite the fact that there was a load of 500,000 lbs. on each truss, the entire structure being completed when the centerings were struck, the cross wires of the instrument never left the mark. Afterwards an additional load of 250,000 lbs. was placed on one truss with a deflection of less than $\frac{1}{64}$ in.





REINFORCED CONCRETE THEATRE IN LOS ANGELES.
Reinforcing steel in 17 ft. truss over auditorium.

Supporting these great trusses are massive columns over 80 ft. long. The cross section of the bottom of the trusses is 16 in. by 60 in., and there are 16 $1\frac{1}{4}$-in. sq. twisted steel bars on the outer or tension side and 12 $1\frac{1}{2}$-in. sq. twisted steel bars on the inside. The steel varies from 12 to 37 ft. long, and, with the exception of the shear bars, which extend down to the balcony level, this column steel is carried down into the footings. The bars are arranged in lengths, so that not more than one-quarter of the steel laps at the same section, and these laps are mostly 4 ft. long with three clamps to each lap. These columns project 2 ft. on the outside of the auditorium walls as pilasters. This was done to give an increased section for the bending moment, and at the same time not to encroach on the theatre space further. These pilasters, of course, extended into the 6 ft. passages required by city ordinance, and in order to preserve the same it was necessary to corbel in, beginning at a point about main balcony level and ending at the walls some 6 ft. 6 in. above the court level. It was safely assumed that the

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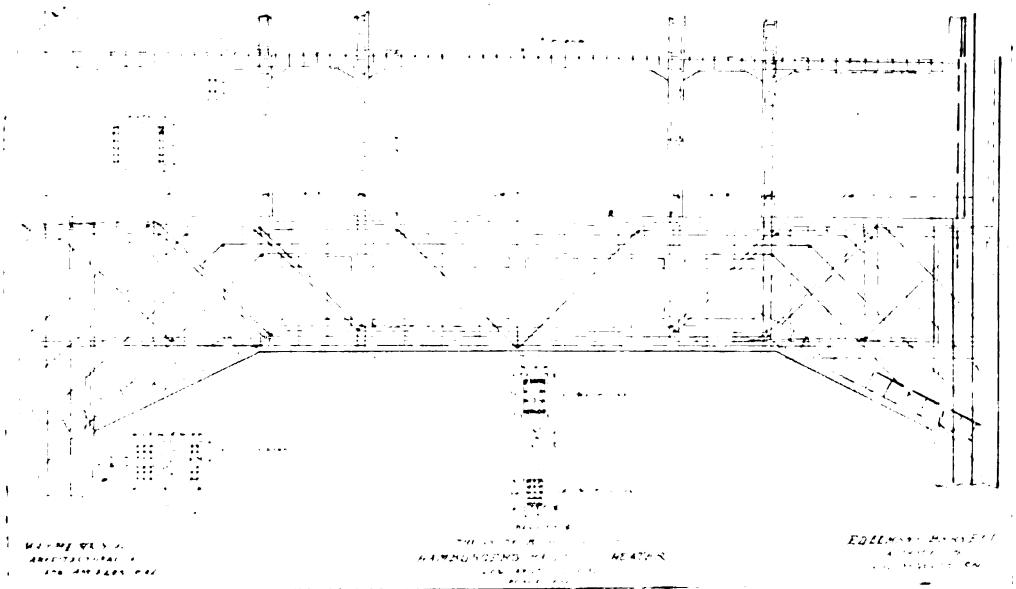

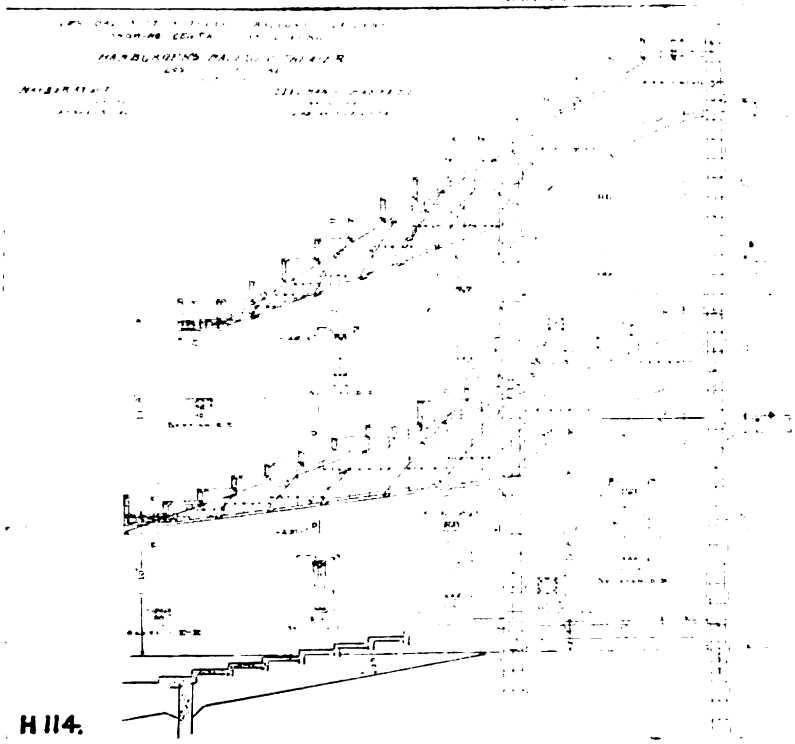

REINFORCED CONCRETE THEATRE IN LOS ANGELES.

Details of truss over auditorium.

Vertical sections through balcony and gallery showing central cantilevers.

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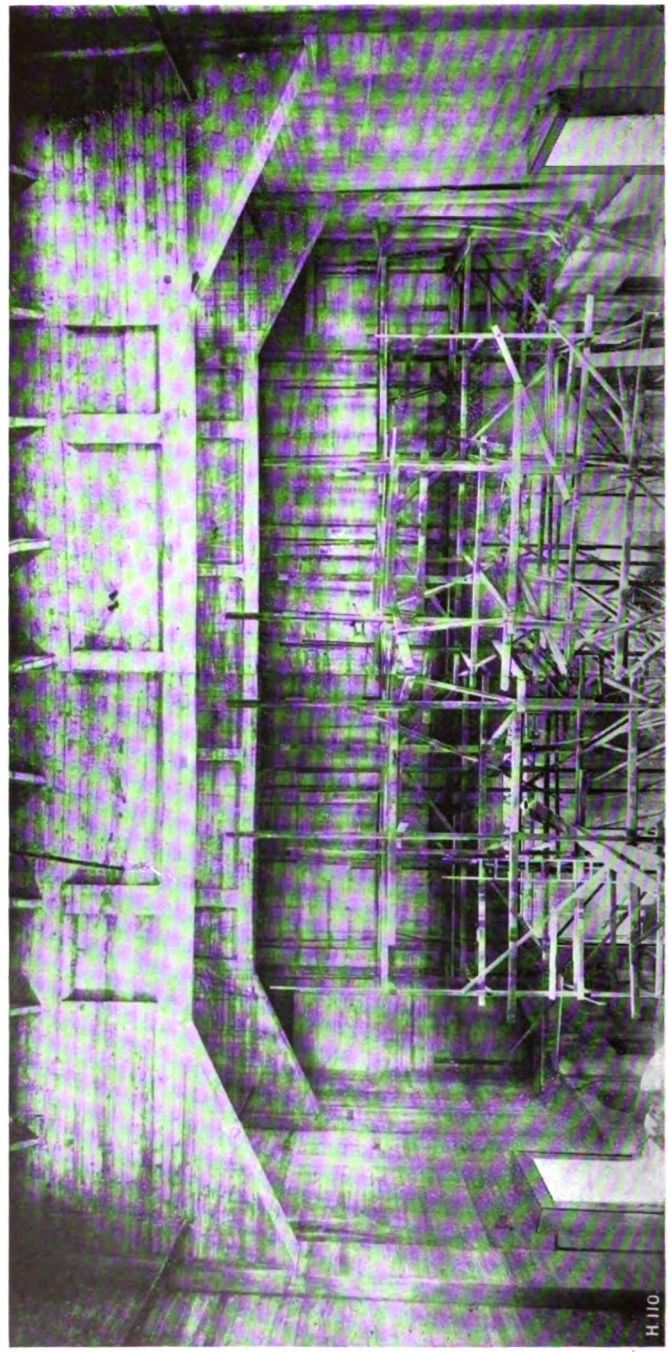
bending moment, transferred to the column from the trusses, would distribute itself into the 18-in. reinforced concrete enclosure walls between the colums that form the side of the auditorium, as well as that the bending moment by that time would be diminished, so that the reduced column section (30 in. by 36 in.) would be sufficient to take care of same.

It was found in the design of these columns that, in order to take care of the large negative moment in the trusses at the support, it would take a column of great size and depth, and in order to keep the size of the column within practical limits, an innovation was introduced. Instead of stopping the truss columns at the top of the trusses they were continued up to the level of the next floor with a slightly reduced section, the latter being 36 in. by 48 in. and reinforced with 12 $1\frac{3}{4}$-in. sq. twisted steel bars on the outside, now in compression, and with 14 of $1\frac{3}{8}$-in. sq. twisted steel bars on the inside, now in tension. In this manner the moment at the connection was distributed between the two sections, and perhaps the only instance of its kind in this medium of construction. Transferring a portion of the bending moment at the support to the upper column section produced considerable thrust at the next floor level, and the amount of



REINFORCED CONCRETE THEATRE IN LOS ANGELES. Reinforced concrete truss over auditorium carrying three story office portion building above.

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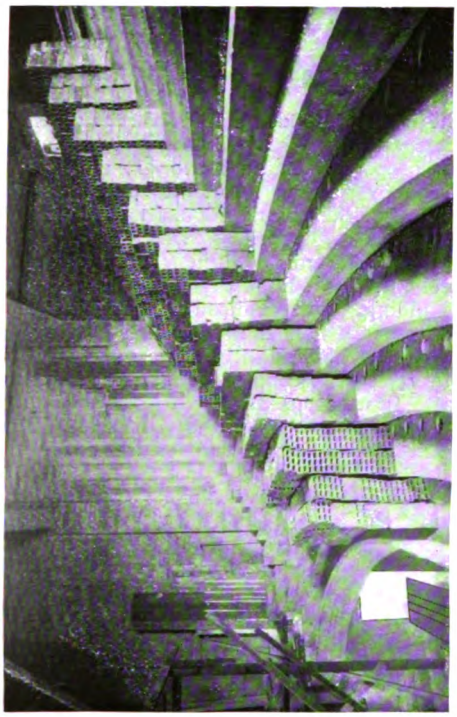
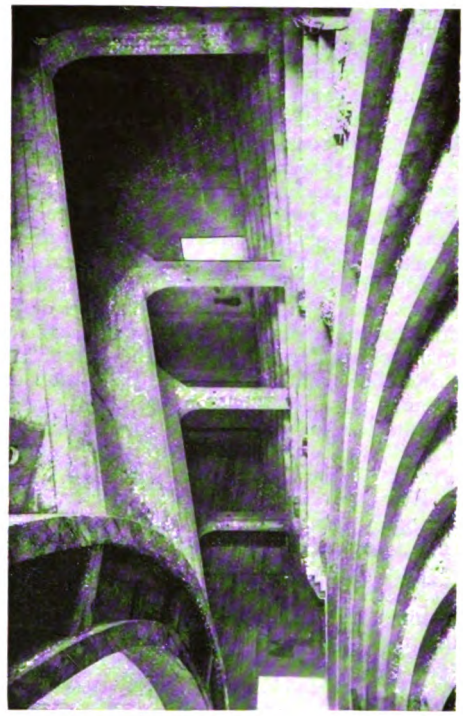
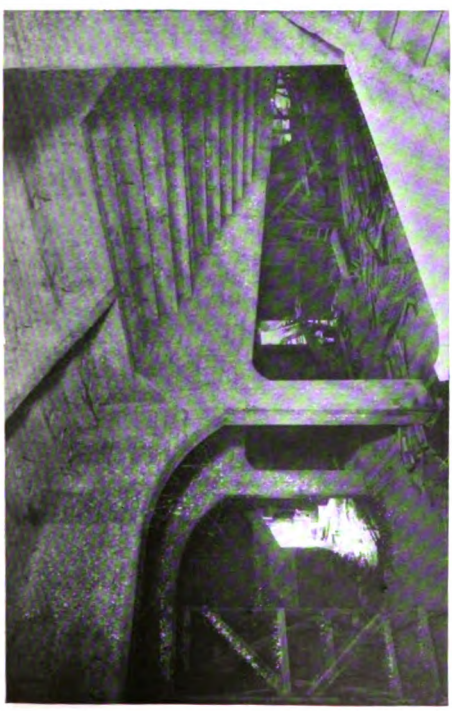


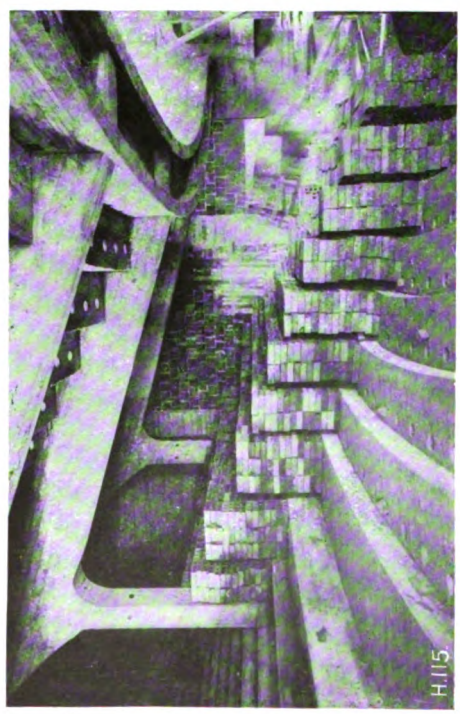
Test load on gallery of 84,700 lbs.



View of balcony and underside of gallery.



Reinforced concrete cantilever supporting balcony.



Test load on balcony of 95,600 lbs.

REINFORCED CONCRETE THEATRE IN LOS ANGELES.

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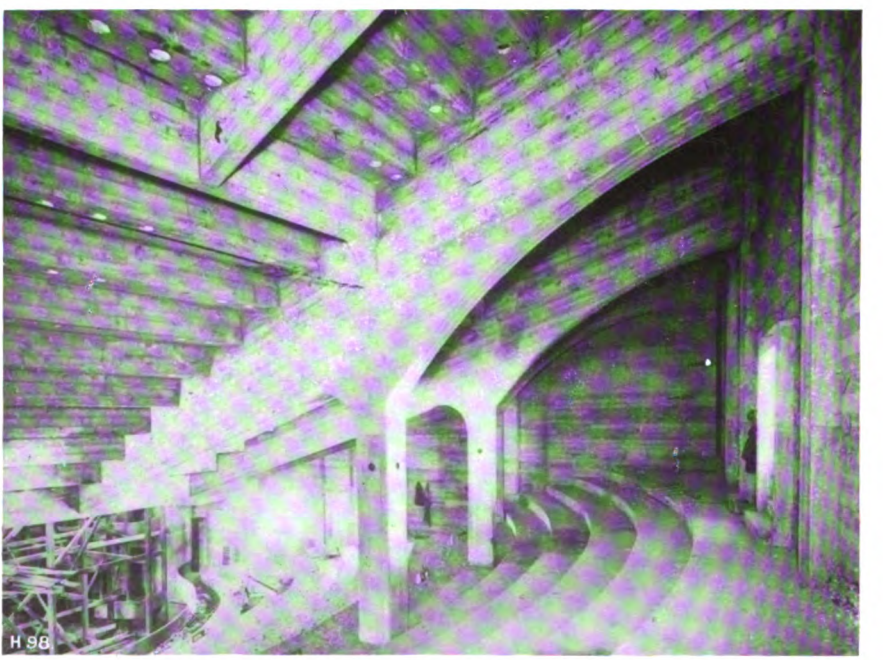
this thrust was assumed to be equivalent to that caused by the maximum moment the upper section was capable of carrying. The transverse beams opposite the columns in this floor were therefore subject to direct compression due to this thrust, as well as to flexure due to floor loading, and they were designed and built as horizontal columns to resist both forces.

The stage is 38 ft. by 80 ft. and 64 ft. high to the under side of the gridiron. The dressing-rooms are on the left in three tiers above the stage floor, and on both sides in the basement. The musicians' room, property rooms, lavatories, etc., are also in the basement under the stage floor. The fly gallery, 11 ft. wide, is on the right, 25 ft. above the stage, and supports one end of the paint bridge, the other end of the bridge resting on a gallery over the dressing room, opposite to which is located the artists' room. This paint bridge is about 55 ft. long, built of light structural steel sections, and is practically the only structural steel outside the fire escapes and suspended ceilings entering into the construction of the building. The gridiron beams, built of reinforced concrete, are suspended from the stage roof beams by looped steel bars, which pass under the steel of the former and over that of the latter. The main stairs in the office front are enclosed on three sides by reinforced concrete walls, 8 in. thick on one side, 4 in. thick on the other two sides. It was necessary to use winders at the return, and this, of course, gives a stair slab with a warped undersurface. The top flight to the roof and pent house makes a full revolution of 360 deg. with a straight flight at each end.

Every seat in the main auditorium will have individual ventilation. There is an opening in the slab directly under each chair, and the space below the slab will be a plenum chamber formed by a suspended ceiling. A damper and deflector will control the quantity and direction of the air current, so as to eliminate any tendency to draught.

Messrs. The Hamburger Realty and Trust Co. were the builders, and the finishing of the office portion of the building is being rapidly completed. Messrs. Edelman and Barnett were the architects, and Messrs. Mayberry and Parker, architectural engineers, designed and supervised the construction of the reinforced concrete work. All are Los Angelos firms.



Reinforced Concrete Theatre in Los Angeles.
View of balcony and reinforced concrete cantilevers carrying gallery.

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CONCRETE AGGREGATES.

PART II.

By DR. JOHN S. OWENS,
A.M.Inst.C.E., F.R.G.S.

We are pleased to see that greater attention is now being paid to the question of concrete aggregates. It has been for so long a matter of custom to give the very closest attention to the quality of Portland cement, the cleanliness of the water, and also to a certain extent to take special trouble as to the sand, but there has all too often been neglect as to the quality of the aggregate.

As to what the aggregate should be, the Special Commission on Concrete Aggregates, formed by the British Fire Prevention Committee, has made some valuable suggestions and drafted some specifications, which were published in our January issue.

In this instance we are presenting a general commentary on the subject.—ED.

When we come to consider the individual characteristics of the various rocks, and artificial substitutes for them, which are used as concrete aggregates, we find that certain of these stand out as having great importance, while others have practically no bearing on the value of the materials for this use.

If we attempt to enumerate the qualities which may be considered important as determining the value of an aggregate material, the following would certainly claim a prominent position in our list :—Hardness, or resistance to friction or abrasion, with its allied quality of toughness, or ability to resist sudden and violent blows or jars; specific gravity, which determines the ultimate weight of the concrete; porosity, or power of absorbing water, a quality the effect of which is often not sufficiently appreciated; power of bonding with the cement, which, though not necessarily connected with it, is in practice intimately associated with porosity; and, finally, the power of resisting fire.

Hardness.—Considering first the importance of hardness, and how it may be measured: It is not quite the same thing as toughness; glass is very hard, but not tough, and the difference between the two qualities is often demonstrated by the behaviour of tough aggregates as opposed to hard when subjected to sudden blows. Hardness cannot be measured absolutely, but sufficient information for our purpose can be obtained. In order to group rocks in the order of their hardness an instrument called a sclerometer may be used. This consists of a lever mounted over a sliding carriage, and pivoted at one end, a diamond point being fixed on the under side of the other end, and the lever weighted over the latter. The stone is placed under the diamond point and caused to move to and fro by means of a weight attached to a string, which, passing over a pulley, is fixed to the sliding carriage containing the test piece. The weight over the diamond point is gradually increased till a visible scratch is made, when its value represents the hardness of the stone as compared with other stones tested in the same way.

A more accurate method is that in which the diamond point is weighted with a constant load, and the stone, mounted on a carriage, is drawn to and fro under the point a certain number of times, the hardness being estimated from the loss of weight of the test piece, or the amount of dust scratched off.

These methods do not, of course, give a quantitative result, but only a comparative. A simple way of attaining the same result with a fair degree of accuracy is to compare each pair of stones by drawing the sharp corner of one over the smooth surface of the other; it will be found that the harder stone scratches the softer. In this way we may proceed by elimination until we find which stone of a group is the hardest. Compared on this basis, a scale of hardness has been drawn up by mineralogists

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consisting of a list of minerals numbered 1 to 10, in which the higher numbers will scratch the lower. This list is as follows:

1. Talc.
2. Gypsum, or rock salt.
3. Calc-spar.
4. Fluor-spar.
5. Apatite (window glass may be used).
6. Orthoclase, or felspar.
7. Quartz (flint may be used instead).
8. Topaz.
9. Corundum, or sapphire.
10. Diamond.

For example, a stone which will scratch felspar but not quartz is said to have a hardness of between 6 and 7. Roughly speaking, a penknife will scratch rocks up to a hardness of 6, and the finger-nail up to about 2. In testing the hardness care should be taken to compare unweathered surfaces, and in the case of rocks having a cleavage the scratch should be made either along or across the direction of cleavage in each case, not along in one and across in another, as rocks are easier scratched in the direction of cleavage than across it.

A more elaborate method of testing hardness has been applied by Mr. Lovegrove, with a view to obtaining the relative values of the different stones for roadmaking. The stones were placed in specially constructed drums, having angle irons fixed on their inner surfaces. All stones were broken to a 2-in. gauge, and 16 stones placed in each drum, which was then caused to revolve 8,000 times at 20 revs. per min. The doors were then opened, and the dust and chips removed and weighed; the former when given as a percentage of the original weight of the stone indicated the degree of hardness, the latter the brittleness. It is important to distinguish between the two qualities. In case a brittle stone on the surface of concrete receives a blow capable of splintering it, the splinters may come away separately, and the empty socket where the stone lay be exposed. This phenomenon can sometimes be observed in works on the foreshore, which are exposed to the blows of boulders.

Specific Gravity—Turning now to the sp. gr. of aggregate materials. The density, or weight per ft. cub., is sometimes misleading, since, unless it is the density of the solid of which the aggregate is composed, it is likely to lead to misconception. The density of a mass of, say, flint gravel may vary much with the shape and size of the particles; if of very uniform grain it may weigh perhaps only 80 or 90 lbs. per ft. cub., whereas another sample of flint gravel having particles of less uniform size may weigh 120 or 130 lbs. per ft. cub. The concrete made from each will, however, have practically the same weight. The sp. gr. of the material is therefore a safer guide, and will enable us to compare the weight of the concrete made from that material with that of concrete from aggregates of different sp. gr.

The sp. gr. of some of the materials commonly used for concrete is as follows:

Basalt	2·7 to 3·2	Limestone	1·9 to 3·0
Flint	2·59	Portland stone	2·37
Granite	2·5 to 2·75	Kentish rag...	2·65
Marble	2·65	Chalk	1·8 to 2·7
Quartz	2·5	Pottery	1·4 ,, 2·0
Sandstone	2·3	Coke	1·00

Porosity.—The porosity of a stone or piece of artificial aggregate may be measured by its power of absorbing water. It is a quality in aggregates which, I am convinced, is responsible for the production of much bad concrete, when its effect upon the behaviour of the cement is not fully appreciated, and the necessary precautions taken. Stones vary much in their power of absorbing water, and when a very porous stone, or dry broken brick, is used for making concrete, with only the quantity of water which is sufficient to bring the mixture to a proper consistence, what happens is this:—The concrete is placed in position in the work, the particles of porous aggregate, which have only had a mere surface skin soaked with water, gradually suck up the water from the concrete, with the result that the cement has not sufficient to enable it to set properly. The proper hydration and crystallization of the cement in contact with the surfaces of the aggregate is hindered, and the bond spoiled. This state of affairs is not improved when the cement is slow setting, such as is now used for reinforced work, as a greater time elapses before the cement can seize on the water. We get, therefore, a poor, weak concrete, with plenty of cement; but not enough water to complete the setting.

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The remedy is clear: we must soak the porous aggregate with water before mixing. The mixing process is assisted by so doing, as the damp aggregate picks up a coating of cement more easily than the dry. This is more satisfactory than adding extra water to the concrete while mixing, as the difficulty cannot be overcome in this way. The saturation of the aggregate is sometimes a slow process, and if sufficient water were added to the mixture to saturate the aggregate it would simply flood the concrete and spoil it.

To compare the porosity of aggregates we must dry the sample to be tested until it ceases to lose weight. It is then weighed, placed in water for 24 hours, and weighed again. The difference will give the weight of water absorbed. If w be the weight dry, W the weight wet, the percentage of water absorbed by weight will be $\left(\frac{W}{w} - 1\right)100$ and if s is the sp. gr. of the stone, the percentage by volume will be given by $\left(\frac{W}{w} - 1\right)$ 100 s.

The absorptive power of various stones is approximately as follows, by weight: Granite, from about 0·1 per cent. to 1·0 per cent.; basalt averages 0·3 per cent.; sandstones from 2·7 to 8·5 per cent.; limestone from 4 to 12 per cent. Brick will absorb as much as 25 per cent. of its weight of water.

Stillman, in his "Engineering Chemistry," gives the following values for absorption of water:

Kind of Material.	Maximum.	Minimum.
Granite	1 in 150	—
Marble	1 „ 150	—
Limestone	1 „ 20	1 in 500
Sandstone	1 „ 15	1 „ 240
Brick	1 „ 5	1 „ 50
Mortar	1 „ 2	1 „ 10

These figures show the weight of stone required to absorb 1 part by weight of water.

Bond.—This is a quality which calls for further investigation. It is not quite certain upon what this bond depends, but it seems probable that it is due to a gripping of the minute irregularities of the surface of the stone between the crystals formed by the cement in the process of setting. Further experimental work relative to this would be of interest, as it is very difficult to be certain that the effect of porosity in the aggregate has been sufficiently guarded against in such experiments as are available. There is a concensus of opinion in favour of rough-surfaced aggregates over smooth, but I am not at all sure that it is based on a sound foundation. It has been shown, for example, that cement will adhere very strongly to the polished surface of glass; also, shingle or gravel composed of smooth waterworn pebbles makes excellent concrete.

Fire Resistance.—The power of resisting fire is sometimes of very great importance. There are certain rocks which undergo a chemical change when exposed to a high temperature, and which therefore cannot be relied on to withstand fire. Ordinary limestone, as is well known, is an example of this class. It consists of carbonate of calcium, which, under the influence of heat, loses carbon dioxide and becomes converted into calcium oxide, as represented by the formula

$$CaCO_3 = CaO + CO_2.$$

The oxide breaks down into powder on wetting.

Other rocks suffer from a sort of mechanical disintegration on exposure to fire, especially if, as is usually the case, they are suddenly cooled by the application of water. Flint is a good example of this type, it flies when heated, and when suddenly cooled splits. On the whole, it may be said that igneous rocks, having been formed at high temperature, resist the subsequent application of heat better than sedimentary rocks, or those formed by crystallization from solution. In the case of artificial aggregates, most of them have already been exposed to great heat, as, for instance, coke breeze, clinker, burnt ballast, broken brick, pottery, and terra cotta; hence they are good fire resisters, so far as mechanical disintegration is concerned. We therefore find that the construction of concrete floors, walls, partitions, etc., in buildings is being carried out more and more with artificial aggregates.

Leaving now the more general characteristics of the materials, we turn to a short consideration of the special qualities of each of those which are commonly used, taking each material separately.

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Limestone.—This rock is composed essentially of calcium carbonate. It is an aqueous rock, or one formed by the agency of water, either sedimentary, as consolidated mud, ooze, and the remains of marine organisms, or deposited out of solution in water. There is often a mixture of magnesium carbonate with the calcium, forming magnesian limestone.

There are innumerable varieties of limestone, varying in texture and hardness from a hard, close-grained, crystalline rock, to mere loose masses of shells, corals, etc. The colour is commonly grey or blue grey, but many other colours occur. The average hardness is about 3; limestone can therefore be scratched with a knife. The density varies a good deal, and averages about 168 lbs. per ft. cub. Its compressive strength averages about 2·10 tons per sq. in., but also varies greatly. As a rule, the heavier the stone the better suited it is for concrete. Some varieties of limestone are very porous, and must be thoroughly wetted before use.

As indicated before, there is one quality possessed by these rocks which make them bad fire resisters: they readily give up their carbon dioxide on heating, forming oxides which break down on wetting.

Concrete made from limestone may be very good or very poor, according to the kind of stone used. Chalk, for instance, such as that forming the cliffs on our South Coast, is useless for concrete, but there are harder varieties which make very fair concrete when mixed with a due proportion of good sand. The oolites make excellent concrete, especially when of fairly fine grain. All the hard crystalline limestones make good concrete, especially the magnesian limestones and dolomites.

The impurities to be guarded against are chiefly dust and clay.

Granite.—This is what geologists call a metamorphic rock, having been formed from already existing rocks, such as clay and sandstone, by the application of great heat deep down below the surface of the earth. It consists of quartz, felspar, and mica, or hornblende, arranged in a coarsely crystalline manner, to which the stone owes its characteristic appearance. There are many varieties found in the British Isles, and all the harder and more finely grained make excellent concrete. The hardness varies somewhat, but the finer grained stones possess a toughness which is a valuable property in concrete for certain types of work, which are exposed to attrition. Its density is from 160 to 200 lbs. per ft. cub., its compressive strength averages 7·45 tons per sq. in., and its power of absorbing water is very small. In fact, good granite should not take up more than 1 per cent. of its weight of water. It should contain about 50 per cent. of quartz, not more than 5 per cent. mica, and the rest felspar. The grain should be fine, and not too coarsely crystalline.

Concrete made with a granite aggregate is very heavy, and does not resist fire very well. It is therefore not so suitable for floors and walls of buildings as if made from other aggregates, but it is excellent for foundations, retaining walls, sea-walls, and such structures, where hardness and weight are advantages.

Flint.—This stone is composed of grey or black silicious matter, probably deposited from solution in water. It is found in irregularly shaped boulders, and thin flat layers in the upper chalk beds. Flints are obtained either direct from the chalk pits, or from the deposits of shingle found in the chalk areas. Casts of shells are often found composed entirely of flint.

The structure of flint is very simple: it consists entirely of silica in the colloid or crystalline form, and is very even in texture. It is exceptionally hard; but also very brittle, hence will withstand a great deal of friction; but breaks under slight blows. It weighs about 162 lbs. per ft. cub., and has an average strength in compression of 3·50 tons per sq. in. The amount of water which it is capable of absorbing is negligible. Flint is a very poor fire resister, whether used as fine sand or in the form of larger stones. This makes the use of concrete made from flint sand, or gravel, such as Thames ballast, unsuitable for all situations where it is liable to be exposed to great heat. Flint concrete is heavy, and although suitable in other respects for sea walls and such structures, its brittleness makes it a bad resister of abrasion, unless the work be faced with very large flints which are capable of withstanding without fracture the blows of boulders driven against them by the waves.

Sandstone.—All sandstones are made up of the remains of pre-existing rocks, and consist of an agglomeration of sand grains, usually quartz, cemented together. The cementing material may be different in different stones. Sometimes it is calcite or

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calcium carbonate, derived from the remains of shells in old sandhills, the rain dissolving them and re-depositing the calcite between the sand grains in the deeper parts; or it may be entirely quartz, or clayey matter. Greywacke is the name given to impure grits and sandstones.

The density is about 150 lbs. per ft. cub. Some varieties are very absorbent, taking up large quantities of water, and when fully saturated lose a large proportion of their strength. Sandstone does not resist fire very well, nor does it withstand abrasion well; but much depends on the quality of the stone used. As in all stones, the finer the grain the better.

Quartzite.—This is somewhat similar to sandstone, being formed from the remains of other rocks. The grains are essentially of quartz sand, and the cementing material is also largely quartz. It is really a metamorphosed sandstone. It is harder and denser than sandstone, weighs about 100 lbs. per ft. cub., resists abrasion well, and is not very absorbent. Concrete made from quartzite is therefore heavy and durable.

Basalts and Diabase Rocks.—These are all of igneous origin. They are medium to coarse grained in texture, the basalts being generally finer than the diabases. The colour is greenish to black.

Basalts are very heavy rocks, the density being about 180 lbs. per ft. cub. Porosity is low and hardness high. The ultimate compressive stress is about 8·6 tons per sq. in., and the resistance to abrasion is very high. Concrete formed from these rocks is very heavy, durable, and most suitable for structures in which weight is an advantage. Although an igneous rock, it does not seem to stand fire very well.

We come now to the artificial aggregates:

Clinker.—This is the partially fused residue from burning coal, refuse destructors, etc. It makes a good hard concrete, but is sometimes honeycombed by bubbles of gas which reduce its value. It is very liable to contain impurities, as sulphur, ashes, dust, and rubbish; special care should therefore be taken to exclude these. Its quality is so very variable that it is difficult to make any general statement as to its value.

Broken Bricks, Pottery, Terra Cotta, etc.—Usually obtained from old buildings, or refuse from brickyards and potteries.

Broken brick makes good concrete, but is a very absorbent material, and therefore requires some care in its use. Care should be taken to remove old mortar, soot, and other impurities. Sooty bricks are liable to cause a stain to appear on the surface of the concrete near which they are.

Pottery is not a suitable material for concrete, owing chiefly to the flat or curved shape of the fragments, which prevents them from bedding well together, and makes them inclined to bridge and form cavities. Otherwise the material itself is good enough.

Terra-cotta fragments make excellent concrete if not too flattened in shape. They require, like broken brick, to be thoroughly saturated with water before use.

Coke Breeze.—This is the finer part of the coke from gas works. Pan breeze is the part which falls through the bars when the retorts are being heated; it is more thoroughly burnt than the ordinary breeze. Coke breeze is very light, and therefore makes a light concrete which is also very fireproof. It is very liable to contain dust and other impurities such as sulphur, and care should be exercised in its use. I have seen concrete made from so-called coke breeze which absolutely refused to set at all, and had to be removed and reinstated.

Breeze concrete is specially suited for suspended floors, owing to its lightness. It possesses also the advantage that it can be nailed to. It is not, however, strong, and should only be used when lightness is of great importance.

Coke breeze weighs about 35 lbs. per ft. cub., hence the lightness of the concrete. It is very porous, but not so absorbent as its porosity would lead one to expect, as the cavities contained in it are mostly closed, being formed by the bubbles of gas evolved during coking. The walls of these cavities are highly polished and dense, but very thin. It is difficult, therefore, for water to obtain access to them. The material is peculiar in structure, and has certain properties which make it valuable as a concrete aggregate.

A scale of quality for road stones has been adopted by the Administration des

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Ponts et Chaussées in France, which is based on the combined results of experiments, on attrition and crushing tests, and on the estimated amount of stone consumed by a certain amount of traffic. As the qualities which go to make a good road stone are practically the same as those which make a good concrete aggregate, this scale is here given. It is taken from Mr. Aitken's book on "Roadmaking and Maintenance." The various rocks are given a numerical value as the simplest means of comparing them, the high numbers indicating the best stones:

Porphyry	10 to 20	Diorite	13 to 17
Trap	16 „ 26	Limestone	5 „ 17
Basalt	10 „ 19	Gneiss	5 „ 17
Quartzite	11 „ 19	Granite	8 „ 16
Grés quartzose	10 „ 20	Millstone Grit	6 „ 16
Flint	8 „ 19	Amphibolite	11 „ 15
Quartz	10 „ 18	Schist	3 „ 15
Serpentine	12 „ 18	Mica Schist	6 „ 13
Melaphyr	16 „ 17	Puddingstone	4 „ 8

This list also indicates the great variation in quality between stones of the same kind; limestone, for example, varying from 5 to 17. Fire resistance is not, of course, taken into account, and must therefore be kept in view if the concrete is liable to exposure to great heat.

In conclusion, should anything in this article serve to stimulate research work relative to the more obscure properties of aggregates, I shall feel that some good has been done. It is only by careful experiments and observation by competent observers that the process of learning by "trial and error," which is so costly both in money and in human life, can be avoided.

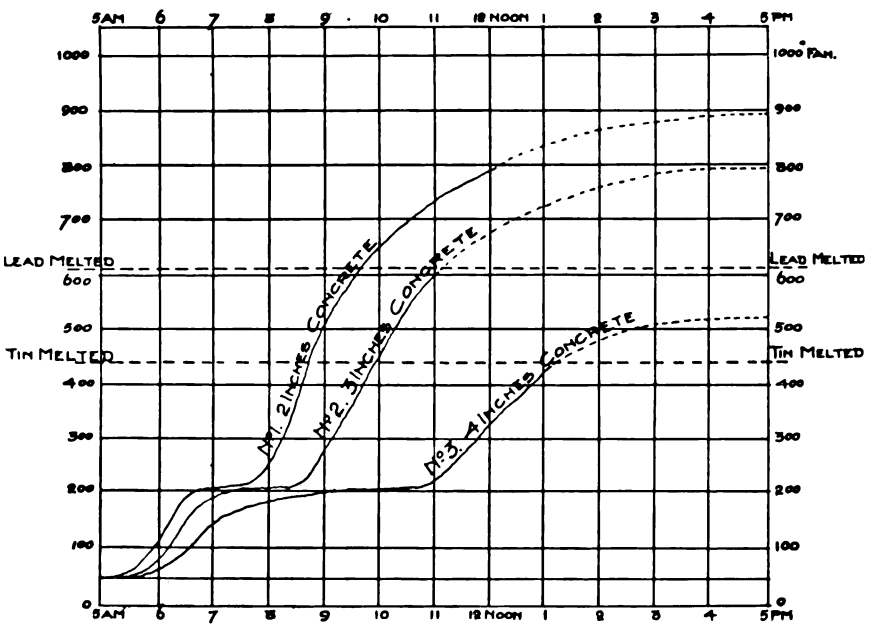

FIG. 4. TESTS ON REINFORCED CONCRETE CONDUCTED IN GREAT BRITAIN. (Diagram.)

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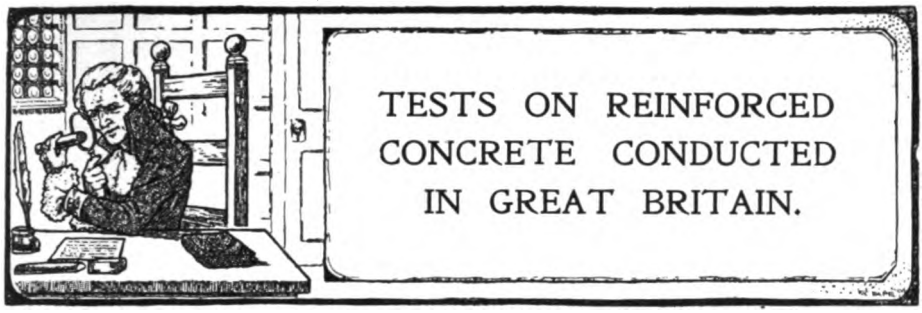

The absence of systematic testing relating to reinforced concrete has placed this country at a disadvantage in the utilisation of this modern material for structural purposes. Excepting only in regard to fire tests, such investigations as have been conducted have been quite spasmodic in character, and practically always of a purely private nature.

Having regard to the fact that the question of a series of tests being conducted in this country, in a systematic manner, is having the attention of the Institution of Civil Engineers, the Concrete Institute, and other scientific societies, we are presenting particulars, as far as we are able, in chronological order, of such tests as have been conducted in this country from time to time, and this may serve as a useful guide to those who have the arrangements of the tests of the future.

To one point only should we like to call attention, and that is to the fact that the first test undertaken in connection with the subject under discussion seems to have taken place as far back as 1874, and that the locale was Mr. Kirkaldy's laboratory.—ED.

VERY little work as regards tests of an experimental character has been done in this country in connection with reinforced concrete. For most of the information upon the subject we are accustomed to refer to Continental and American authorities; the chief experimental work has been done in France, Germany, and the United States.

It is regrettable that more has not been done in England, because practice is somewhat different; the very fact that English methods of manufacturing Portland Cement are different, while the aggregates and sands are, of course, local and not to be accurately classified as equivalent to the materials in other countries, renders it most desirable for us to investigate the subject to a great extent under our own conditions.

It has been thought desirable, however, to collect together all the data as regards tests that have been conducted in England and recorded in sufficient detail to make them of scientific value. The data have been collected mostly from private sources, as the number of official tests are very few indeed. Each of the tests carried out privately has had for its object the proof that the design and construction of certain specific work on proprietary systems or in particular buildings was safe and practically satisfactory.

The tests upon actual structures in this country have been fairly numerous, but, unfortunately, full particulars have not been kept or are unavailable, so that no scientific value can be attached to them, and as nothing could be gleaned from them as regards our present purpose we have excluded them from this review.

The private individuals and firms who have undertaken tests deserve commendation, for they have performed a service to the community, and particularly to the engineering and architectural professions, which we had no right to expect. Our public institutions, who should have assisted in experimental work, have, unfortunately, been very remiss, for there is practically nothing to place beside the elaborate and highly commendable researches carried out by engineering professors in public laboratories in the United States, Germany, and France. Even our Colonies have done something in this direction, though the Mother Country has omitted to do anything. The only exception that stands to our credit are the official tests carried out upon the

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fire-resistance of special systems of reinforced concrete construction conducted by the British Fire Prevention Committee. These tests are especially noteworthy, as very little has been done in this direction; the United States is practically the only country that has carried out any number of such fire tests. But the methods of the United States are open to considerable criticism, and we venture to express the opinion that methods there adopted are not so thorough, and do not provide information nearly so reliable as that provided by the British Fire Prevention Committee.

The First Tests.

Though our record of tests, other than fire tests, is not so extensive, nor so thorough as that of other countries, we can, however, claim the credit of not only having had as a countryman the first inventor of what may be termed reinforced concrete in the modern sense, which Mr. W. B. Wilkinson, of Newcastle-on-Tyne, first patented in 1854, but of having had probably the first scientific series of experiments carried out in England—namely, a series of tests on reinforced beams invented, designed, and manufactured by an American, Mr. Thaddeus Hyatt, who obtained chief notoriety in the building trade through his invention of pavement lights, which he appears to have been the first to introduce in New York for the lighting of basements, meeting with considerable success in that field, as a consequence of which he came to this country to open a branch office, which is still in existence.

Mr. Hyatt had evidently been working for many years through a process of thought leading to the subject, because he had some tests carried out in the hydraulic press of Mr. R. G. Hatfield, of New York—firstly, on June 2nd, 1855, on a plate or beam of plaster of Paris, reinforced, if we may so call it, with hollow tin tubes running longitudinally through it. This was followed, on June 8th, with a test on a single tin tube filled with mortar and a tube filled with plaster of Paris. On April 25th a model of a beam, made of blocks of wood held together by a tin band and tin plates arranged vertically between the blocks and another piece on the top of these plates to confine the blocks, was tested; while on September 12th, 1855, a brick beam, 5 ft. long, made of flat bricks about 9 in. sq. and 1 in. thick, confined by a tie-rod near the bottom passed through holes made for the purpose in the bricks, was also tested.

The Hyatt Tests of 1870.

Apparently Mr. Hyatt came to England in 1870, or a little previous to this date. At the time there must have been very few testing machines or engineers prepared to undertake tests on structural materials. So far as we know, the only testing machine at all suitable for testing beams was that which the late Mr. David Kirkaldy had constructed in Southwark Street, London. Mr. Hyatt, therefore, took the opportunity of availing himself of the facilities which were offered by Mr. Kirkaldy's enterprise in specialising in the testing of materials and in the construction of plant suitable for large tests to resume his attempts to devise improved methods of fire-resisting construction. Firstly, in the year 1870 he had some tubular beams constructed of iron and concrete, of the section shown in *Figs.* K5551-5557, the particulars of the breaking load applied at the centre being given in the table on page 115. In 1874 Mr. Kirkaldy tested some reinforced brick beams for Mr. Hyatt, but the latter stated he became convinced of the greater practical value of concrete for floor and roof construction and continued his experiments with reinforced concrete beams during the latter part of 1876 and early part of 1877. The results obtained in the above-named tests, together with the details of construction of the beams, are given in the tables.

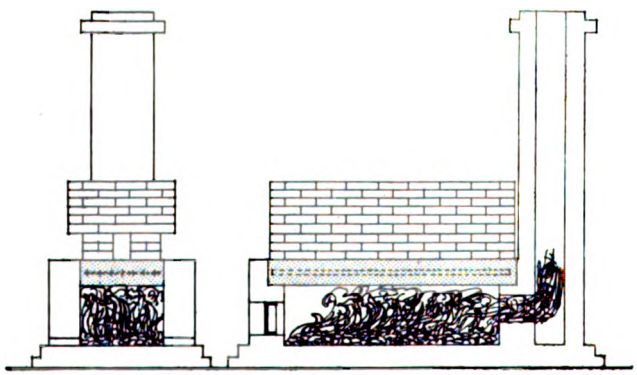

Fig. 1. Fig. 2.

Trial of Reinforced Concrete Floor Section with Fire and Water.

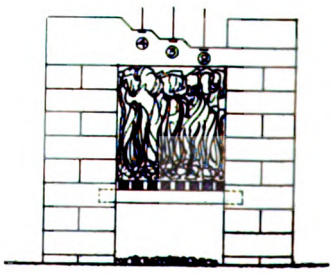

Fig. 3. Test for Thermal Conductivity of Concrete.

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HYATT'S TESTS.

General Particulars.—The cement used was stated to be Best London Portland. The concrete was made with 2 parts crushed stock bricks to 1 of cement, mixed by hand, and its compressive resistance in cube form was estimated by Hyatt at 2,000 lbs. per sq. in. The reinforcements were of wrought iron. The tests were carried out by David Kirkaldy in 1877 on his standard methods, and the load in each case was centrally applied. The beams when tested were from 2 to 3 months old.

No. of Test.	Nature of Beam Tested.	Dimensions.	Clear Span.	Details of Reinforcement.	Breaking Load.	Hyatt's Remarks.
		L'gth. Width D'pth.	ft.		lbs.	
K5544	Plain cement, rectangular beam.	6′ × 12″ × 8″	5	None.	3,192	—
K5537	Plain concrete, rectangular beam.	6′ × 12″ × 8″	5	None.	1,484	—
K5559	Concrete beam, with firebrick slabs across, 2″ thick by 11″ apart.	9′ × 8″ × 9″	8	$3\frac{5}{8}$″ rods below, $2\frac{3}{8}$″ rods above. Total weight, 31 lb.	13,512	Concrete crushed, rods not broken.
K5558	Firebrick tiles 1″ thick with $\frac{1}{8}$″ cement between each.	9′ × $10\frac{1}{2}$″ × 9″	8	$2\frac{5}{8}$″ rods below, $2\frac{3}{8}$″ rods above. Total weight, 33 lb.	10,513	Bricks parted, rods not broken.
K5560	Ditto.	9′ × 8″ × 9″	8	Ditto.	11,983	Broke through tile, rods not broken.
K5561	Firebrick tiles flatwise; seven courses.	9′ × 8″ × 9″	8	3 lengths of hoop-iron $1\frac{1}{4}$″ × $\frac{1}{16}$″ between each of two bottom courses, and vertical bolts through each tile. Total weight, 24 lb.	9,084	Bricks crushed, one tie out of 6 broken.
K5542	Concrete.	6′ × 12″ × 8″	5	$5\frac{3}{8}$″ round iron ties below, riveted to heel plates, and $2\frac{3}{8}$″ rods above, 5 cross-plates of sheet iron 12″ × 6″. Total weight, $26\frac{1}{2}$ lb.	12,348	Parted at sheet iron, ties not broken, but pulled through.
K5536	Cement.	6′ × 12″ × 8″	5	Ditto, but cross plates 6″ deep.	14,496	Parted at sheet iron, ties not broken, but pulled through.
K5547	Concrete.	6′ × 12″ × 8″	5	Ditto.	13,583	Ties not broken, pulled through.
K5549	Concrete.	6′ × 12″ × 8″	5	$5\frac{3}{8}$″ round iron ties below, riveted to heel plates, 2 upper rods in form of bent ties coming down between bottom ties in middle, and 2 plates across 12″ × 6″. Total weight, $22\frac{1}{2}$ lb.	15,478	Ties not broken; strength due to the bent ties furnished with threaded ends and nuts.
K5550	Concrete.	6′ × 12″ × 8″	5	$5\frac{3}{8}$″ round iron ties below, riveted to heel plates; $2\frac{3}{8}$″ rods above; 5 cross plates of sheet iron 12″ × 6″. Total weight, $26\frac{1}{2}$ lb.	12,178	Ties not broken, very faulty, pulled through.
K5548	Concrete.	6′ × 12″ × 8″	5	$5\frac{3}{8}$″ round iron ties below, no top rods, and no heel plates; rods upset only.	9,274	Ties not broken, pulled through.
K5545	Concrete.	6′ × 12″ × 8″	5	3 plates of iron 6″ × $\frac{1}{16}$″, and 1″ × $\frac{1}{4}$″ ties riveted on both sides of each plate below, the iron plates crossed by 5 ranges of $\frac{1}{4}$″ wire 3″ apart. Total weight, $67\frac{1}{2}$ lb.	29,628	Concrete crushed, iron ties buckled but not broken.
K5546	Concrete.	6′ × 12″ × 8″	5	Ditto, but wires 6″ apart. Total weight, 60 lb.	28,022	Ditto.

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HYATT'S TESTS—*Continued.*

No. of Test.	Nature of Beam Tested.	Dimensions.	Clear Span.	Details of Reinforcement.	Breaking Load	Hyatt's Remarks.
		L'gth. Width. D'pth.	ft.		lbs.	
K5539	Concrete.	6′ × 12″ × 8″	5	7 plates of iron 6″ × $\frac{1}{16}$″, crossed by 18 wire rods $\frac{1}{4}$″ diam. Total weight, 62 lb.	25,148	Iron broken at rivet holes.
K5543	Concrete.	6′ × 12″ × 8″	5	7 plates of iron 5″ × $\frac{1}{16}$″, crossed by 18 wire rods $\frac{1}{4}$″ diam. Total weight, 52 lb.	25,868	Ditto.
K5538	Concrete.	6′ × 12″ × 8″	5	7 plates of iron 4″ × $\frac{1}{16}$″, crossed by 18 wire rods $\frac{1}{4}$″ diam. Total weight, 41 lb.	23,884	Ditto.
K5541	Concrete.	6′ × 12″ × 8″	5	7 plates of iron 3″ × $\frac{1}{16}$″, crossed by 18 wire rods $\frac{1}{4}$″ diam. Total weight, 31 lb.	21,222	Ditto.
K5540	Concrete.	6′ × 12″ × 8″	5	7 plates of iron 2″ × $\frac{1}{16}$″, crossed by 18 wire rods $\frac{1}{4}$″ diam. Total weight, 21 lb.	16,418	Ditto.
L841	Concrete.	6′ × 12″ × 12″	5	Flat iron tie 2½″ × ¼″, placed 2″ from bottom, ends turned up and riveted to heel plates, and tie also supported by 2½″ bolts, 8½″ long and 23″ apart. Total weight, 25 lb.	15,938	Concrete given way, ties moved in concrete but not broken.
L872	Concrete.	6′ × 12″ × 12″	5	Ditto.	20,346	Ditto.
L842	Concrete.	6′ × 12″ × 12″	5	Ditto, but with bent in place of straight tie.	16,386	Concrete given way, tie not broken.
L873	Concrete.	6′ × 12″ × 12″	5	Ditto.	18,066	Ditto.
L843	Concrete.	6′ × 12″ × 12″	5	Flat iron tie 2½″ × ¼″, placed 2″ from bottom, supported by 4½″ bolts 23″ apart; no heel plates. Total weight, 38 lb.	16,344	Concrete crushed, tie drawn out.
L874	Concrete.	6′ × 12″ × 12″	5	Ditto, but 28 lb. stated as total weight (? printer's error).	19,328	Iron tie broken at bolt hole.
L844	Concrete.	6′ × 12″ × 12″	5	Ditto, but supported by 7½″ bolts 11½″ apart. Total weight, 31 lb.	18,084	Tie broken at bolt hole.
L875	Concrete.	6′ × 12″ × 12″	5	Ditto.	17,110	Ditto.
L845	Concrete.	6′ × 12″ × 12″	5	Ditto, but supported by 10½″ bolts 8″ apart. Total weight, 33 lb.	19,024	Ditto.
L876	Concrete.	6′ × 12″ × 12″	5	Ditto.	19,584	Ditto.
L846	Concrete.	6′ × 12″ × 12″	5	Ditto, but supported by 19½″ bolts 4″ apart. Total weight, 40 lb.	21,592	Ditto.
L877	Concrete.	6′ × 12″ × 12″	5	Ditto.	18,866	Concrete crushed, tie not broken.

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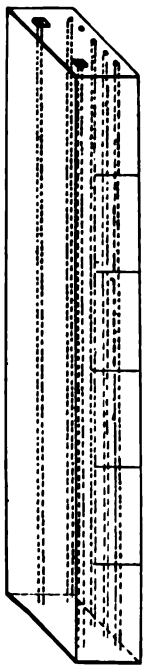

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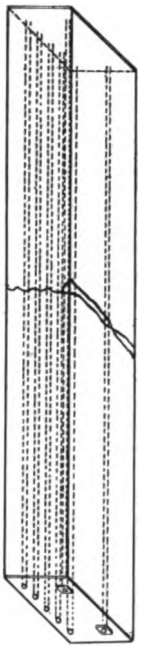

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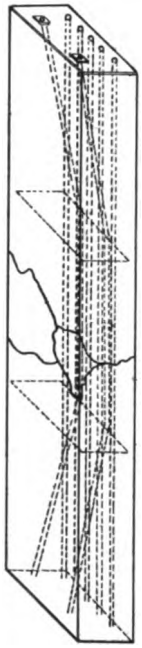

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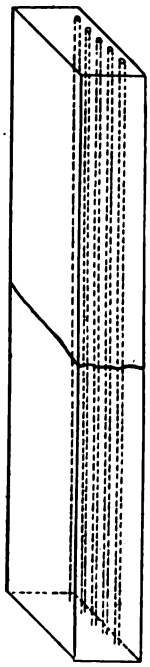

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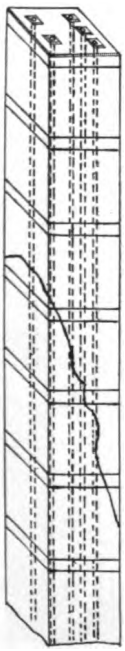

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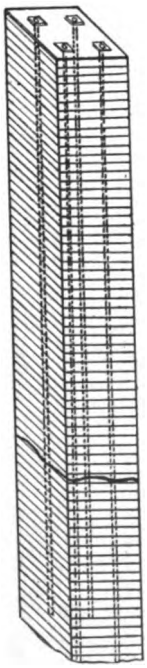

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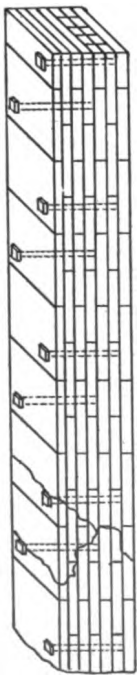

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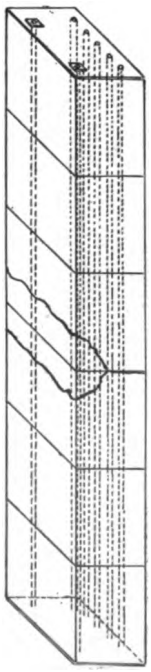

K5542.

HYATT'S TESTS ON REINFORCED CONCRETE BEAMS

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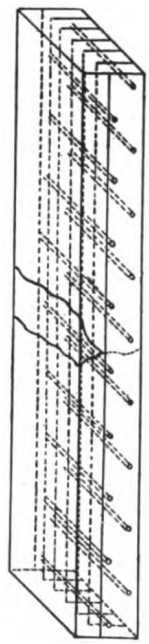

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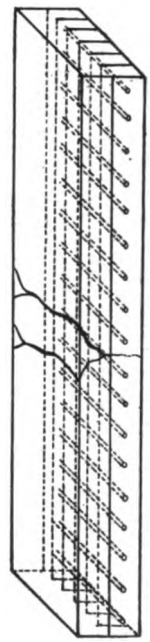

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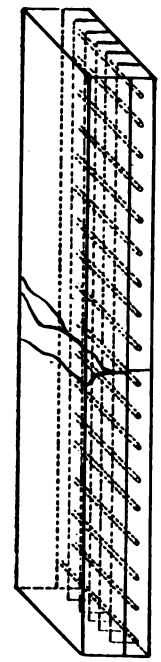

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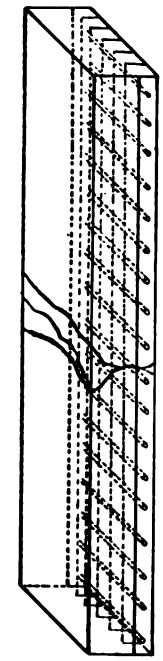

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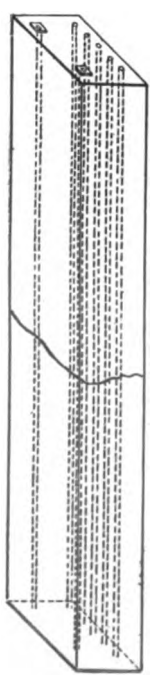

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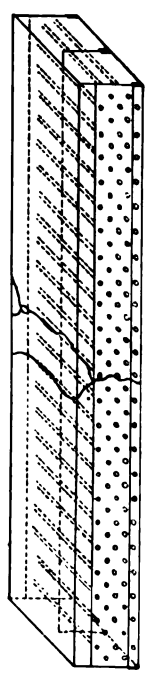

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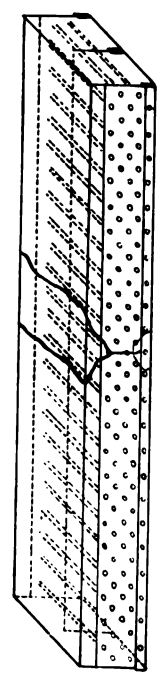

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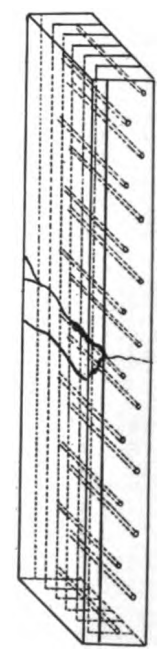

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HYATT'S TESTS ON REINFORCED CONCRETE BEAMS.

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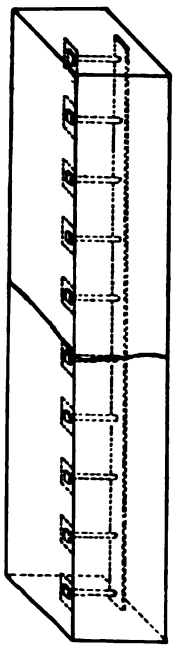

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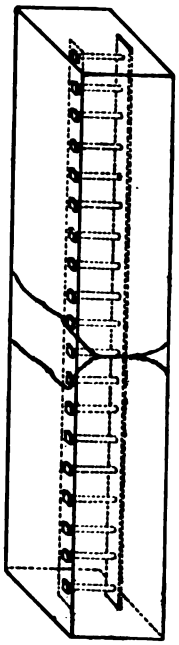

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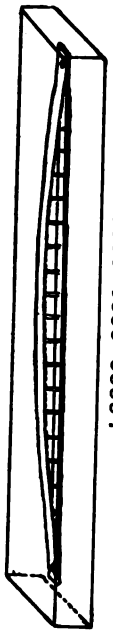

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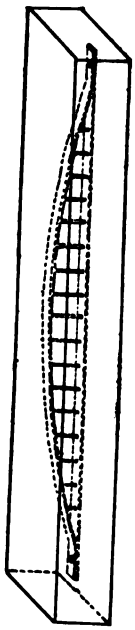

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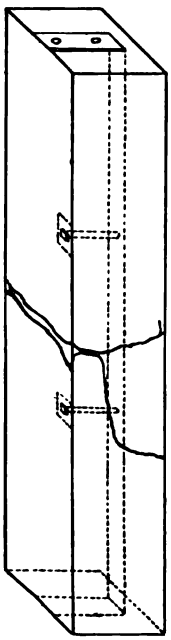

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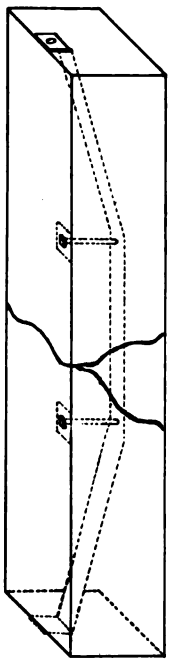

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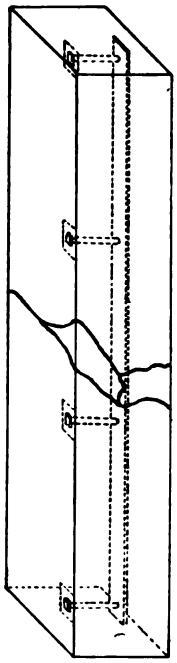

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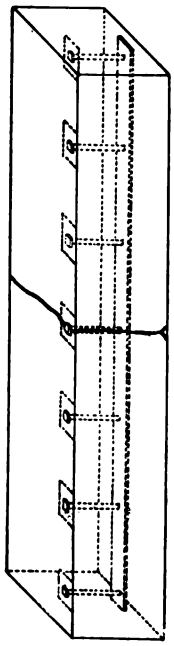

L844.

HYATT'S TESTS ON REINFORCED CONCRETE BEAMS.

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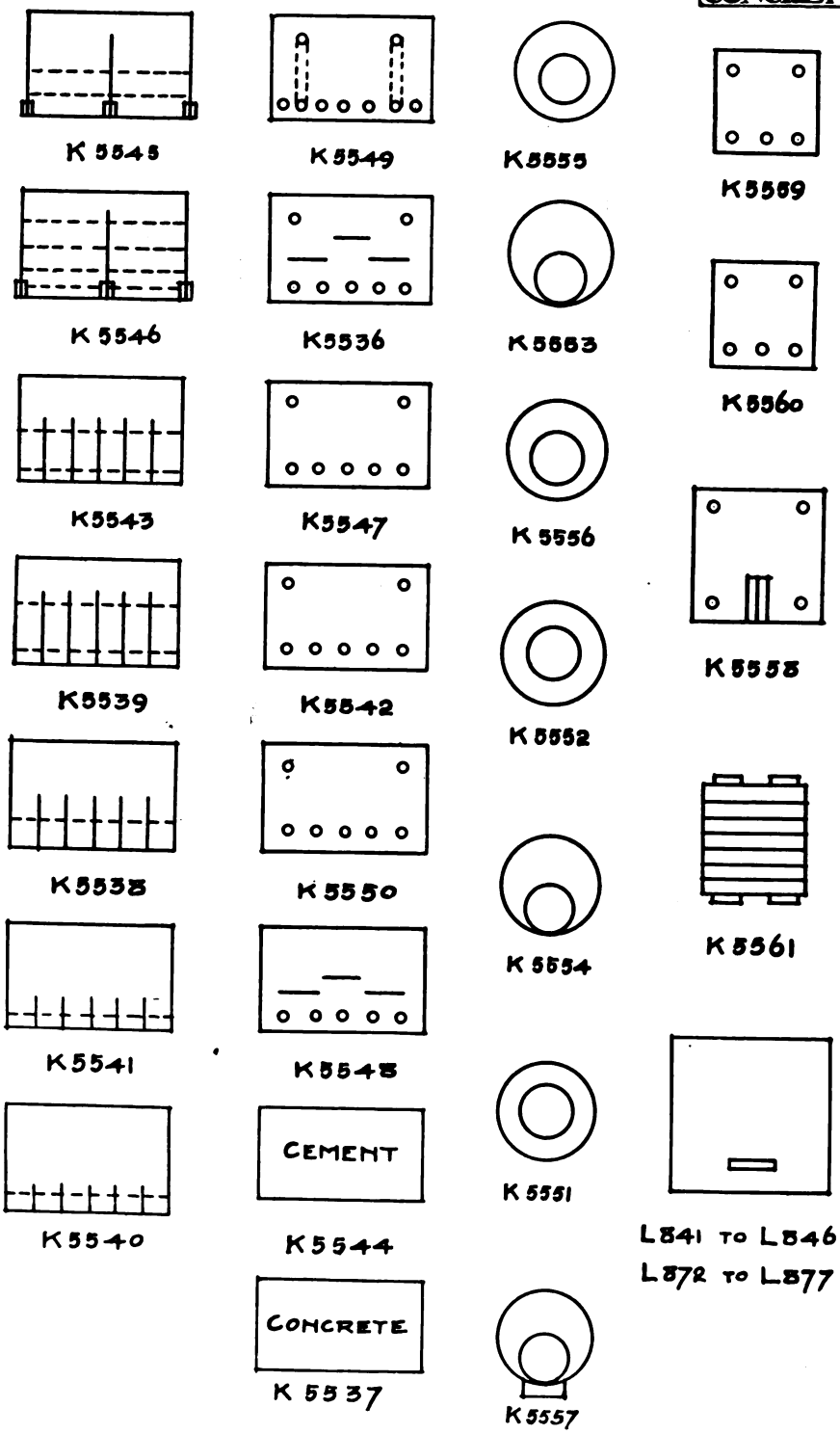

SECTIONS OF HYATT'S REINFORCED CONCRETE TEST BEAMS.

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No. of Test.	Nature of Construction Tested.	Dimensions.	Clear Span.	Details of Reinforcement.	Stress cracked.	Deflection.	Ultimate Load.
			ft.		lbs.		lbs.
K5555	Circular beam (apparently concrete).	Diam. Abt. 8″	6	Sheet iron. Details not given.			27,483
K5553	Ditto.	Ditto.	6	Ditto.	—	—	26,892
K5556	Ditto.	Ditto.	6	Ditto.	—	—	25,174
K5552	Ditto.	Ditto.	6	Ditto.	—	—	23,468
K5554	Ditto.	Ditto.	6	Ditto.	—	—	22,720
K5551	Ditto.	Ditto.	6	Ditto.	—	—	21,236
K5557	Ditto.	Ditto.	6	Ditto.	—	—	17,916
L2222	Concrete beam.	9¼″ × 4⅛″	5	Details not given, but appears to be about 1⅛″ × ¼″ hoop iron, in two layers the upper arched and connected by rods.	3,168	·51	3,472
L2221	Ditto.	9⅛″ × 4¼″	5	Ditto.	2,644	·57	2,891
L2220	Ditto.	9⅛″ × 4⅜″	5	Ditto.	2,572	·54	2,572
L2223	Ditto.	9″ × 5⅛″	5	Ditto.	4,032	·28	5,288
L2225	Ditto.	9″ × 8⅛″	5	Ditto.	3,968	·28	5,208
L2224	Ditto.	9⅛″ × 5⅛″	5	Ditto.	3,734	·29	4,574
L2228	Ditto.	9″ × 6⅛″	5	Ditto.	5,568	·27	6,377
L2226	Ditto.	9⅛″ × 6¼″	5	Ditto.	6,232	·39	6,232
L2227	Ditto.	9⅛″ × 6½″	5	Ditto.	4,942	·27	5,472
L2230	Ditto.	9⅛″ × 7⅛″	5	Ditto.	7,241	·24	8,824
L2229	Ditto.	9⅛″ × 7⅜″	5	Ditto.	7,509	·28	8,739
L2231	Ditto.	9⅛″ × 7½″	5	Ditto.	7,249	·24	8,237
L2233	Ditto.	9″ × 8⅛″	5	Ditto.	8,362	·20	11,211
L2232	Ditto.	9⅛″ × 8⅛″	5	Ditto.	7,832	·21	10,684
L2234	Ditto.	9⅛″ × 8½″	5	Ditto.	8,266	·26	9,428
L2236	Ditto.	9⅛″ × 9⅛″	5	Ditto.	10,386	·29	11,731
L2235	Ditto.	9⅛″ × 9⅜″	5	Ditto.	10,434	·25	11,462
L2237	Ditto.	9⅛″ × 9½″	5	Ditto.	10,012	·26	10,816
L2238	Ditto.	9⅛″ × 9½″	10	Ditto.	6,044	·58	7,747
L2239	Ditto.	9⅛″ × 9⅛″	10	Ditto.	5,868	·60	7,216
L2240	Ditto.	10⅛″ × 9½″	10	Ditto.	5,014	·72	6,389
L2241	Ditto.	12⅛″ × 9″	10	Ditto.	7,572	·41	8,588

Some Additional Tests.

Mr. Hyatt was very thorough in his investigation on the subject, and he also carried out a test upon the fire resistance of concrete on a floor of reinforced concrete of the type shown in *Figs.* 1 and 2. In one of his tests he constructed a furnace and roofed it with a slab of concrete of three different thicknesses, as shown in *Fig.* 3. Flat bars of iron were let into each step with the effect of leaving 2 in. of concrete under one, 3 in. under another, and 4 in. under the other. Two small squares of metal, one being tin and the other lead, were let into each bar of iron. Upon these rods or needles were made to rest, as shown in the drawing, the ends being connected with weights in such a way that on the melting of the metal the needle would sink and thus indicate the exact degree of heat at the time. Preliminary degrees of heat, however, were taken with thermometers, and the final degree at the end of twelve hours—the close of the experiment—was ascertained by drawing the hot bars from the concrete body and plunging them into vessels of water provided with thermometers, the rise of the temperature of the water indicating the heat of the irons at the time of the immersion. From this data the thermal chart reproduced in *Fig.* 4 was constructed.

Mr. Hyatt recorded the fact that: "It will be observed on examining the chart that the thermal lines as they approach the boiling point of water remain in that vicinity for some considerable time, the explanation of which is that this length of time was required for the evaporation of a certain amount of free moisture contained in the concrete, after which the temperature again continued to rise as before. It will also be noted that the thermal line of the 3 in. thickness of concrete is higher than the mean between the 2 in. and 4 in. thicknesses, which may be accounted for on the ground of its position at the centre of the top of the furnace."

Expansion of Cement.

To ascertain the limits of expansion and contraction of Portland cement within indefinite ranges of temperature, trial sticks of cement were made and heated, the expansion of the same being measured by placing the sticks between two fixed points, space being allowed between, the variations in which were ascertained by means of tapering pieces. The result was found to be a lineal expansion of ·0017 for 180 deg. of heat as compared with ·0014 for wrought iron. As Mr. Hyatt states: "A result so near equal that the expansion might be considered to be the same." However, in order to prove the result practically, blocks of concrete 14 in. long, 4 in. deep by 3 in. broad were made, in which bars of iron were embedded, these bars varying in size from 2 by $\frac{1}{32}$ in. to 2 in. square and 12 in. long. On testing these by fire no difference in effect was found to be produced on the concrete by the different masses of metal contained within them. As a final test, bars of iron 2 ft. long by ½ in. thick were embedded in blocks of concrete, which, on being exposed to the red heat of a furnace for six hours, were found to be entirely sound and good when taken out.

Mr. Hyatt acknowledges the assistance given to him in his investigations by Mr. Thomas Rickett, an engineer of Birmingham, formerly for 10 years in the employ of the London & North-Western

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Railway; and perhaps it is as much to him as to Mr. Thaddeus Hyatt that we may attribute the understanding displayed on the points required to be investigated for a determination of the distribution of stresses in reinforced concrete beams and calculations as regards strength. In Mr. Hyatt's book the question of the neutral axis is dealt with, and experiments conducted in this direction described. He had a test conducted on a bar of cement 10 days old with two fixed points inserted therein 50 in. apart, one of the points being the bent end of a rod lying upon the outside of the bar of cement parallel with it, which rod extended to within a short distance of the other point, thus leaving a space sufficiently small for accurate measurement on the cement being subjected to pressure. To prevent bending, the cement bar was braced with a frame fitting loosely about it, yet sufficiently tight for the purpose. The load was applied gradually by means of a lever, the actual compression from time to time being ascertained by tapering pieces which were measured by the gauge. In this way the compression was ascertained to amount to ·048 in. in 50 in. with a load of 1,000 lbs. per sq. in., the bar returning to its original length on removal of the load. This gives the ratio of expansion as ·00096 of length for 1,000 lbs. per sq. in., or "in round numbers the 1-1000th part of length; and if the ultimate compressive strength is taken at 2,000 lbs. per sq. in. (which Mr. Hyatt thought was perhaps the safe figure, considering that concrete in practice, and not neat cement, would form the compressive member of the compound beam) the final compression would be the 1-500th part of length. Now, as wrought iron was found to extend the 1-10,000th part of its length for every ton of strain per sq. in., it follows," said Hyatt, "that at 20 tons, or, say, prior to rupture, it will extend the 1-500th part of its length, or about the same compressibility of cement; the effect of which, in the compound beam, is to keep the neutral axis at the centre line of the beam, the entire tensional strain being thrown upon the metal tie. The results of the Kirkaldy tests already alluded to confirm these conclusions." So much for Hyatt's and Mr. Rickett's view of the distribution of stresses. It was a pity they did not test the compressibility of concrete instead of cement, although the insight and carefulness displayed by these investigators was surprising, and if they had been checked by any other engineers at the time we might not have had to wait so long for the advent of the reinforced concrete age.

They endeavoured to measure the ratio of expansion by similar means, but they stated that, as the range of tensile strength in cement was limited, it was not possible to determine the point with the same accuracy, the result being only ·000042 of length for 100 lbs. per sq. in., or, say, the 1-10,000th part of length as final expansion before rupture. This sample at the same age of 10 days yielded a tensile strain of 224 lbs. per sq. in.

Test by Fire and Water.

As regards the test by fire and water on a section of a Hyatt floor, a furnace was built as shown in *Fig.* 17, the top being a slab or floor section 6 ft. long by 2 in. wide by 7½ in. thick; the metal was placed in the middle, 3 in. of concrete being above, and 3 in. below. The furnace was made with a range of airholes on either side to ensure perfect combustion, and a load was placed on the top of 300 lbs. per sq. ft. over the whole surface, the deflection being with this load $\frac{1}{32}$ in. in a span of 5 ft. The fuel was arranged to form an incandescent mass 12 in. thick below the upper surface of the concrete slab. The fire, being kindled at six o'clock in the morning, had by eleven o'clock—*i.e.*, in five hours—become an intense heat perfectly uniform over the entire surface, and the bottom of the concrete was at a glowing red heat all over. At this intensity the fire was kept up until 4 p.m.—namely, 10 hours from the lighting of the fire. During this time the slab had deflected ⅜ in. A stream of cold water was now thrown forcibly against the bottom of the slab for a period of 15 or 20 minutes by means of a force pump, and the load was removed. On examining the underside of the section it was found uninjured, and the next morning, being then entirely cold, the deflection had disappeared, the slab having returned to its former level. A second trial was made, this time the load being left upon the slab, which, during the firing, deflected as before, but upon cooling returned to its original level, lifting the load with it. As evidence of the heat of the furnace it is recorded that the faces of all the side bricks in actual contact with the fire were melted.

In addition to the experiments described, Hyatt states that he conducted others as to the non-conducting power of various substances, such as plaster of Paris of different densities, and concretes more or less porous, also with air spaces, but he does not give details: he only states that the results of all of them was that the best material to protect the metal against heat was found to be that which was strongest in compression—namely, Portland cement of the best quality, no advantage for any purpose being found from fibres of any kind, not even asbestos.

As regards the concretes used in these experiments by Hyatt, the compressive strength is stated to have ranged from 500 lbs. to 5,000 lbs., according to the quality of the materials and the skill and fidelity of the workmen. He took, as a basis for calculation, the ultimate compressive resistance at 2,000 lbs. per sq. in.

The concrete apparently was proportioned, 2 of crushed stock bricks to 1 of Portland cement; the size of the aggregate is not stated.

(To be continued.)

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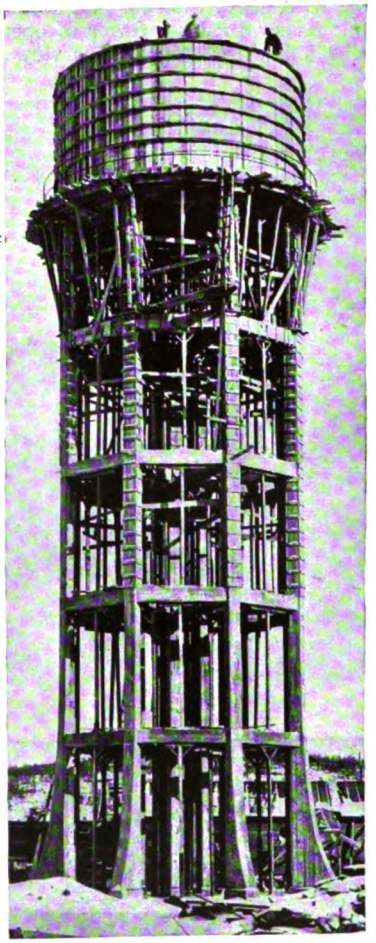
SOME CANADIAN WORKS RECENTLY ERECTED IN REINFORCED CONCRETE

From time to time we have presented illustratea articles on factories built of reinforced concrete, in different parts of the Empire. On this occasion the factory we describe is in Ontario, Canada, and the illustrations and short description indicate how entirely suitable reinforced concrete is for this class of work.—ED.



REINFORCED CONCRETE WATER TOWER.

THE chemical mills of the Wood Products Company at Donald, Ontario, comprise four buildings, an oven-house, still-house, charcoal-house and boiler-house, also a 50,000-gallon concrete water tower and small concrete dam.

Sand from the site of the mills was used in all of the concrete. The stone used was peculiar in its fracture, in that it was semi-splintered, with very little dust, and was more in the nature of a flint limestone than anything else. For foundations, etc., 2½-in. mesh screen stone was used, while for the superstructures two grades of stone, one passing ½-in. or ⅝-in. screen and the other passing a 1-in. screen, were used. The combination of these two grades, in connection with the sand used, made an exceedingly dense concrete. The reinforcement for the beams throughout the entire works consisted of "Niagara" bars, which had sufficient elasticity in form and application to cover all of the requirements of reinforced concrete.

The oven house claims some interesting features in connection with the structural side of the work. The entire roof-work is carried by six reinforced concrete columns resting on arched or divided footings standing between the ovens. The still house, which contains the neutralising room, tank room, main distilling room and refinery, presents some interesting points, too. It was necessary to provide an exceedingly strong floor system to carry four 10,000 gallon tanks, for holding raw liquor, at an elevation of 14 ft. 6 in. above grade with an ample factor of safety. At the opposite end of the still house in the refinery openings 9 ft. 6 in. dia. were left in the floors for the alcohol still to pass through. These floors have been figured for a safe loading 450 lbs. per sq. ft. on the second and 350 lbs. per sq. ft. on the third and fourth floors respectively. In the centre or main room of the still house it was deemed necessary to carry the roof on some very high columns, 22 in. dia. and 23 ft. in height. These columns were poured in one operation from the top, a specially graded mixture of concrete enabling the base of the column to be poured without separation of the aggregate.

In the main part of the still house, as in the charcoal house, there is another roof carried on girders of approximately 32 ft. span, with secondary beams connecting therewith, running longitudinally with the building carrying the monitor walls. Staircases throughout are constructed entirely of reinforced concrete with unsupported landings, and the windows and frames are of a special type of double rabbeted factory

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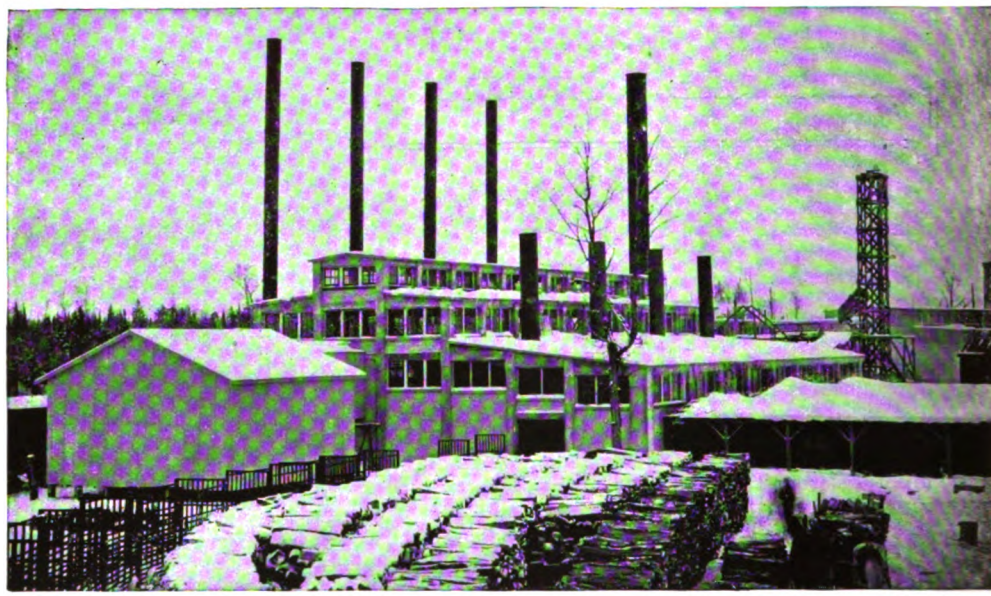
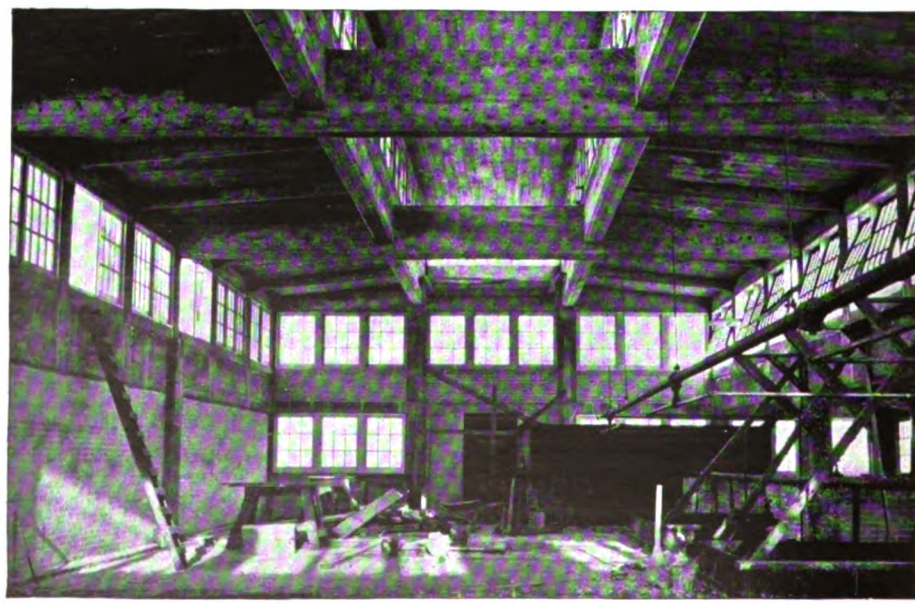
type with heavy muntins; all sashes are pivoted hung. The reinforced concrete water tank rests on a high tower of open-work construction, which is the first of this type to be built in Canada. Our view shows 4 16-in. columns at the corners of the box



REINFORCED CONCRETE PLANT OF THE



INTERIOR OF ACETATE ROOM OVER THE OVENS IN OVEN HOUSE.

column. The tank is of 50,000 gallon capacity, and stands 93 ft. in height from grade line to top of the roof. Use was made of the space between the four central columns as a hoistway, the hoisting being done with a small belt-driven drum

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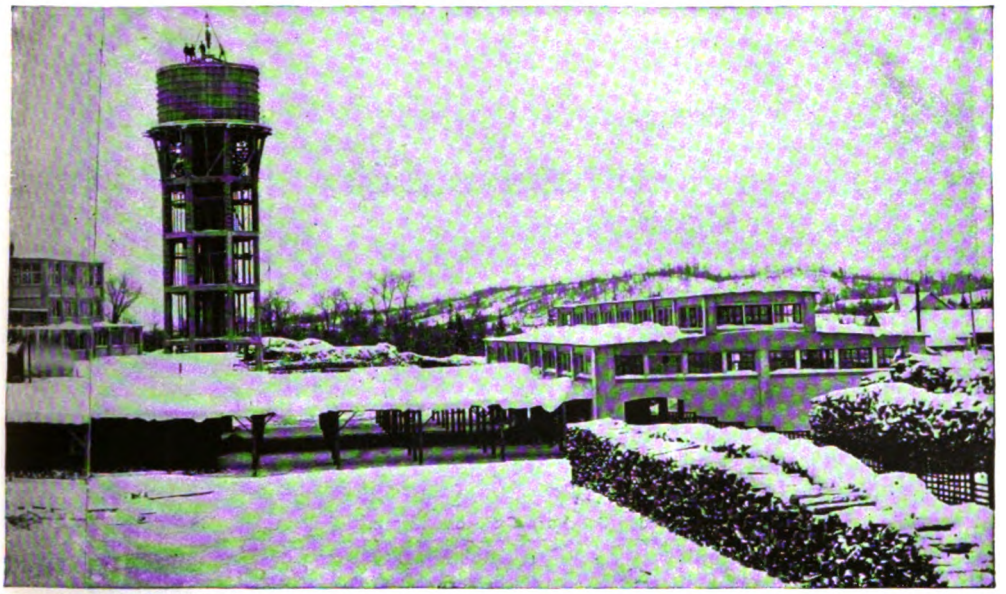
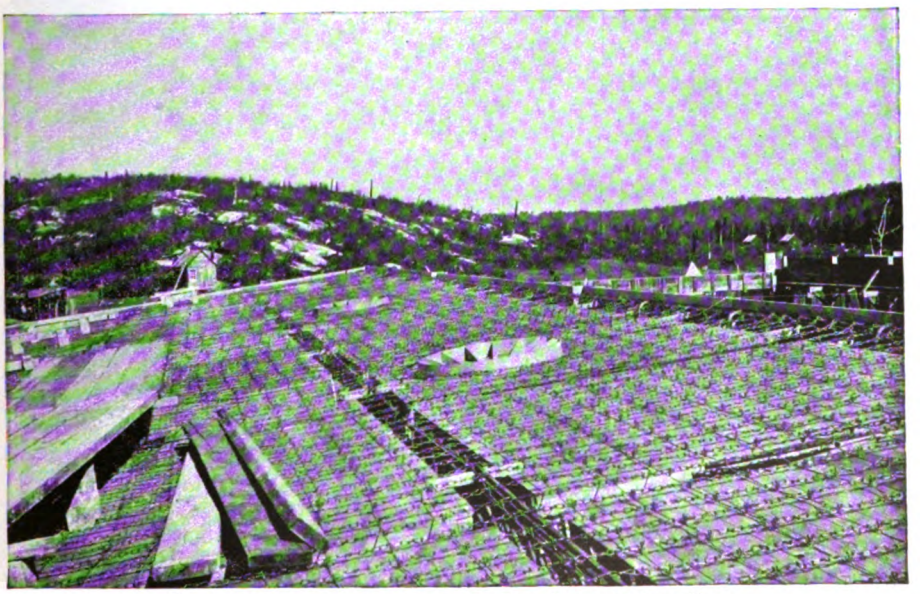
attached to a shaft in the planing mill immediately adjacent to the water tower. A tripod with 14-in. boom block in the peak supported the hoist. This was carried from floor to floor as the work progressed, until finally the entire framework of the tank



Wood Products Company, Donald, Ontario.



Chain Reinforcement for Concrete Roof Slabs of Oven House.

including the roof, was set in place, and the tripod stood on the top of the roof formwork. The bucket was hoisted to the peak of the roof and the concrete allowed to flow down the slope, dropping into the side walls of the forms. Twisted steel bars were used almost exclusively as reinforcement in the tank.

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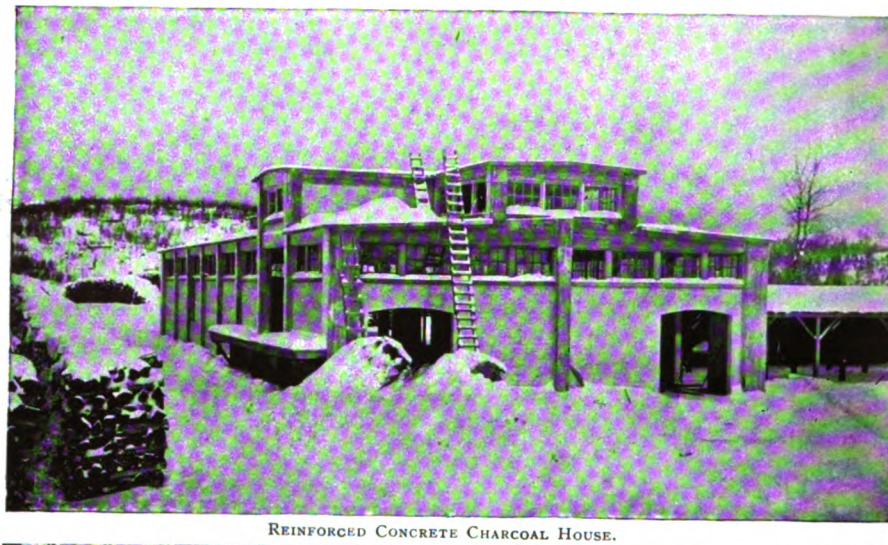
A concrete dam 214 ft. long, exclusive of the wing walls, for carrying a normal head of about 9 ft. of water, was thrown across an adjacent river to give water for cooling the stills, and here, too, reinforcement of twisted bars was incorporated into the body of the dam to prevent the possibility of structural cracks.



REINFORCED CONCRETE CHARCOAL HOUSE.

CONCRETE DAM IN COURSE OF CONSTRUCTION.

The steel chain fabric for slab reinforcement was used in unison with the "Niagara" bar to great advantage. In addition to that bar for bottom reinforcement in beams and girders, plain squares and flat steel negative reinforcement bars were used throughout the work.

The illustrations are presented by courtesy of the *Cement Age*, New York.

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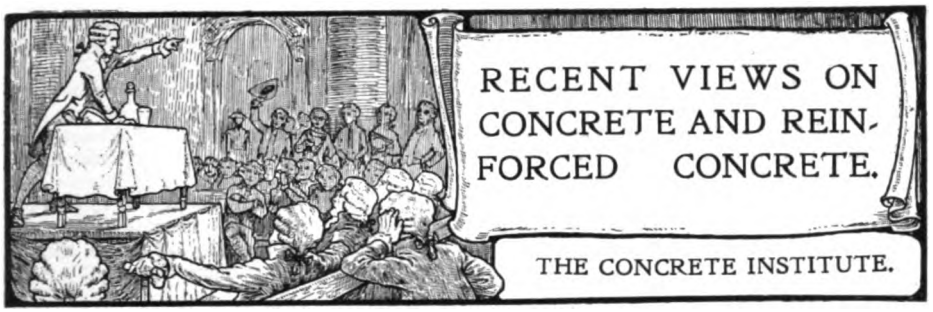

It is our intention to present the Papers and Discussions of the Concrete Institute in a concise form, and in such a manner as to be easily available for reference purposes.

The method we are adopting, of dividing the subjects into sections, is, we believe, a new departure.—ED.

THE March meeting of the Concrete Institute, which was held, as usual, at the Royal United Service Institution, was devoted to a paper and discussion entitled "Concrete in Arched Bridge Construction," the reader of the paper being Mr. E. P. Wells, J.P., Honorary Treasurer of the Institute.

The paper was one of exceptional excellence, broad in tone, practical in detail, and illustrated by some excellent examples of bridge work, both drawings and photographs being thrown on the screen.

The meeting was presided over by Mr. A. Ross, M.Inst.C.E., Chief Engineer of the Great Northern Railway, the discussion being opened by Prof. Adams, M.Inst.C.E.

As to the Institute's work, we are only taking the opportunity on this occasion to point out that the Institute has now been incorporated, and the conditions of incorporation and rules have been circulated among the members. It is a matter of congratulation that the incorporation of this Institute has been completed with such rapidity, and, speaking generally, both the conditions of incorporation and the rules appear to be equitable, but it is quite possible that they may not quite satisfy all the individual members, whose ideas on such a subject inevitably vary considerably. With the incorporation of the Institute, that body has entered upon a new phase of its work. It is to be hoped that its progress will continue as satisfactorily as it commenced. As we go to press, we understand the membership has reached 600, which is certainly a far stronger membership than we anticipated a year ago when the Institute was first mooted. The appreciation with which the formation of the Institute has been received is shown by the fact that a very large number of its members are civil engineers, architects, and surveyors of high professional standing and with a large practice.

The offices of the Institute are at 1 Waterloo Place, London, S.W., temporarily, to which address enquiries should be directed.

THE FOURTH MEETING.

CONCRETE IN ARCHED BRIDGE CONSTRUCTION.

PAPER by E. P. WELLS, J.P., Hon. Treasurer of the Institute.

Mr. Edwin O. Sachs, F.R.S.Ed. (Chairman of the Executive), opened the proceedings by announcing that the roll of members and subscribers at the date of the meeting totalled nearly 580.

The Chairman, Mr. Alex. Ross, M.Inst.C.E., then asked Mr. Wells to read his paper.

MR. E. P. WELLS, J.P., Reader of the Paper.

The materials used in the construction of arches in this country, the lecturer said, had been confined in the past to stone, bricks, iron, and steel; and it was seldom that any other materials were used, unless it were for arches of very small spans, many engineers and architects, for reasons of

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extreme caution and safety, being indisposed to use concrete. But the use of Portland cement concrete was more satisfactory, not only as regards strength, but also as to first cost, an item which, at the present day, had in many instances to be seriously considered.

One of the principal reasons why concrete had not been more often used in this country was the fact that very few engineers had ever seriously experimented with this material; they had only considered it good enough for retaining walls and foundations, and some engineers did not place much faith in it, even for the latter work; and where it was used it was very often made abnormally strong for fear of accidents happening.

The lecturer knew of cases where the loads on the foundations did not exceed 2 to 2½ tons per sq. ft., and the concrete was made in the proportion of 4 to 1; whereas this material would carry with perfect safety 100 tons per sq. ft. two months after being made. assuming, of course, that all the materials were good and clean and the Portland cement was of the ordinary best quality made and not adulterated.

Advantages of Concrete.—There was a homogeneity about concrete, when properly made, that was not obtained where bricks or stone were used; and those who had had to pull down structures built of either stone, brick, or concrete, the lecturer thought, would agree with him that concrete was not the material he would prefer. His experience was that good concrete well rammed was a most difficult material to break up when made *en masse;* and if by any possible chance iron had been used in combination, then it required dynamite or some other explosive to shatter it.

The lecturer explained that he intended to confine himself principally to pivoted arches, which were theoretically and practically the only form of plain concrete arches that ought to be constructed, and he would show how pivoting at both the springings and centres came to be adopted.

Curve of Equilibrium.—Previous to the adoption of the pivot at both the springing and centre of the arch, it was felt by German engineers that some method should be adopted whereby the curve of equilibrium could be absolutely confined within the centre third. It was well known that in a stone arch it was almost impossible to ascertain where the curve of equilibrium would run, as everything depended on perfect construction, especially in the grouting of the joints, etc.; any defects in grouting up would cause an alteration in the curve of equilibrium, and in all probability might endanger the safety of the structure. It was this difficulty in bedding stones of large area that had compelled engineers to put such a large amount of material in stone arches so as to be on the safe side.

Settlement of Stone Arches.—To show what effect settlement had on a stone arch the lecturer called attention to the shore span of Waterloo Bridge on the Surrey side, where it was found upon examination that the abutment moved about half an inch, the result being that the joints opened at the keystone, and the whole thrust of the arch passed through a few inches of the extrados. This had caused the voussoirs to spall, and a further movement of half an inch might cause serious mischief to this national monument.

Some years ago a bridge was constructed in Germany where mortar joints were dispensed with, and in place thereof sheet lead was used, each piece of lead being made the area of the centre third and fixed on the centre third of the stone. This overcame the difficulty to some extent, as the curve of pressure was compelled to pass through the centre third; but this method of construction was expensive, as the arch stones had to be very carefully dressed to an even thickness, so that all joints were linable throughout, or the thrust in the arch would have been very unevenly distributed. The lecturer believed only one bridge on this principle was constructed; but another bridge was built—viz., at Kirchheim—where only lead was used at the springing and centre, covering about one-sixth of the cross-sectional area of the arch. It was left to the late President von Liebbrand, the chief engineer to the State of Würtemberg, to adopt the method of pivoting in its application to the concrete and stone arches; and the adoption of this principle had enabled the State of Würtemberg to erect concrete bridges of large spans all over the country, where the use of stone would have been undesirable on account of cost.

Pivoted Bridges. — The first pivoted concrete bridge from the design of the late President von Liebbrand that was constructed in Würtemberg was a large one—viz., 164-ft. span—and was the pattern in respect to facilitating erection, reducing the dimensions in the arch, and the use for the first time of the pivot at the springings and centre, which since then had been invariably adopted for concrete arch construction on the Continent, excepting those cases where the concrete had been reinforced with steel, and the arches made with fixed springings and practically continuous from abutment to abutment.

CONSTRUCTION OF CONCRETE BRIDGES.

The lecturer then proceeded to describe the construction of a concrete bridge having a span of 150 ft. with a rise of 19 ft. This bridge, the dimensions of which he gave, was strong enough to carry the heaviest possible vehicular traffic as also the heaviest railway traffic, and to carry a load of over

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3 cwt. per foot super on one half, with the other half unloaded, and all this without the use of steel in its construction; but if steel were used then the loads could be very materially increased.

The principal reason why these concrete bridges were so safe under unequal loading was due almost entirely to the pivots at the springings and centre, which compelled the curve of pressures to pass through the same, the only sensible variation in the curve being at the haunches; even the loading given would not in any case alter the curve so that it passed above or below the middle third. Such being the case, it would be observed that no part of the arch could be in tension; but should such a thing happen theoretically, the spandril walls, by their great rigidity, would prevent any distortion of the arch; and, if the spandril walls and tables were reinforced, it would be possible to put a tension of 10 to 15 tons in either the extrados or intrados without the structure collapsing or changing its form.

Another advantage that a concrete arch possessed over a brick or stone arch was its homogeneity, there being an absolute lack of joints which were an element of weakness, as was the mortar in the joints—*e.g.*, in the case of a granite arch, $\frac{1}{20}$ the crushing strength of the stone itself if made of lime and $\frac{1}{8}$ the strength if cement grout were used. Then why use a material that was stronger than the weakest part?

The Arch. — In designing a concrete arch it would be found necessary to start on the assumption that the thinnest part of the arch—viz., at the centre—is approximately $\frac{1}{50}$ of the span. This you must increase at the springing by about 7 per cent., and at the haunches by about 27½ per cent., to allow at this point for varying loads tending to make the curve of pressures rise or fall either below or above the neutral axis, and so to always keep the said curves within the middle third.

Having then apportioned the sizes of the spandril walls, or spandril pillars, to the loads that the bridge is intended to carry, also the intermediate tables and tables to carry the vehicular and foot traffic, proceed to ascertain the weight of the structure and find the curve of equilibrium for the dead load only. Having ascertained that, make it the neutral axis of the arch, and alter the shape of the extrados and intrados by compounding the curves so as to make both equidistant from the neutral axis. The normal condition of a concrete bridge was its dead load, and the greatest stresses were set up by the dead load; so the lecturer considered that, unless extraordinary loads were to be passed over the bridge, it was not necessary to take into account the live load, especially if it were only ordinary or vehicular traffic. If the curves for equally distributed loads and also for one-half of the arch loaded were worked out it would be found that the curve of equilibrium at the haunches did not vary more than 3 in. either above or below the neutral axis. In the case of a heavy rolling load, it was only when the load was at the centre of the span, or a few feet on either side of it, that the increased stresses at that point in the arch could be accurately calculated, because nearly the whole width of the arch, from the point under the load to the springing, took up the stresses induced, and the same were reduced to a minimum by the enormous area of arch that they were spread over. The reason why concrete arches were so strong was that the stresses induced by the weights were so well distributed; otherwise there would no doubt be distortion of the arch and great deflection at the centre, whereas in no case, where exhaustive tests had been carried out, had this been proved,

Under these circumstances it was perfectly permissible to reduce the thickness of the arch until the stresses amount to 36 tons per sq. ft.; but it would then be required to ascertain the positions of the curves of equilibrium for dead load, equally distributed live load, and also for one-half of the arch loaded, and likewise for the maximum rolling load placed in the centre of the span. The neutral axis could then be made the mean of all the curves.

The effect of this would be that at the haunches, for dead load only, the compression at the intrados would be slightly increased, and correspondingly reduced at the extrados; the curve of the intrados would not require so much compounding, but would be more segmental in form, unless they were placing excessive dead loads on the haunches, when the curves of pressure would rise, and so enable the curves of the intrados to be compounded and the appearance of the arch very materially improved.

If it were possible in concrete arch construction to make the arch so that the dead load were equally distributed, then the curve of equilibrium would be a parabola; but the appearance of the arch would suffer, though theoretically correct.

Spandril Walls.—In all cases the spandril walls, and also the concrete filling over the arch beyond the spandril walls at the centre, should be bonded to the arch by means of stone figs, or old iron rods, in the shape of bolts, etc., etc., as by this means any separation taking place between the extrados of the arch and the spandril walls could be absolutely prevented, and the cementitious nature of the concrete had not to be depended upon, which was not always desirable unless very great care be taken in roughing the concrete and making the same absolutely clean.

Centerings.—The centres needed for the erection of a concrete arch were similar in every way to those required for a stone or brick arch, with this exception, that less strength was wanted, owing to the fact that a concrete arch weighed less.

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Where it was required to construct the whole arch of concrete, and make imitation stone voussoirs, special shuttering must be made. This could be moulded to any desired form; but great care must be exercised in fixing the shuttering and in well strutting the same, so that in making the concrete voussoirs the ramming did not cause the shuttering to bulge. The shutters for concrete voussoirs could be formed out of 2-in. to 2½-in. wood strengthened with rails, etc., the surface exposed to the concrete being machine wrought; but it was not essential that they should be of an even thickness, as a slight variation would, when the voussoir was constructed, act as a key. On the top of the laggings the thickness that the concrete voussoirs were required to be formed should be marked off, the shuttering fixed, the faces in all cases being radial to the curve, and care taken to thoroughly well strut the shuttering, so as to prevent undue distortion in consequence of the weight of concrete. After this was done, the surface of the laggings should be covered with about 1 in. of 1 part sand to 1 part Portland cement (made dry) and then, as rapidly as possible, concreting commenced; the quicker the concrete was put in and well rammed the stronger and better it would be. When once a concrete voussoir was started it must be finished without a break; and sufficient men should be employed, so that, from start to finish, not more than two hours would elapse. When about three-fourths of the voussoir had been finished, the stone figs or iron rods, etc., should be built in for bonding the spandril walls to the extrados of the arch.

After the concrete was set, the surface should be covered over with wet sacks, and kept well wetted during the whole time that it is exposed.

Order of Fixing Voussoirs.—It was advisable, when forming the concrete voussoirs, to always place the first voussoir between the points of support of the centres, not over the supports; thus, if any deflection was caused by the weight, it was put into the beam before the remaining voussoirs were made.

In closing in with the voussoirs Nos. 3, 5, 7, 9, and 11 care should be taken that the faces of the existing concrete voussoirs were thoroughly clean and well roughened; and, as the concrete was brought up, neat cement grout or 1 to 1 cement mortar put on the faces of the existing concrete, so that a perfect bond was obtained between the new and the old. When ramming the concrete care should be taken that the existing faces of the voussoirs were not in any way damaged. To prevent this it was advisable to use special hardwood rammers. Lest, by any chance, the faces of the voussoirs previously put in should be honeycombed, some 1 to 1 mortar should be used to fill up all interstices previous to the concrete being filled in.

After the completion of the voussoirs Nos. 2 to 12 it became necessary to adjust the granite blocks.

Pivots.—The pivots should be made of the best annealed cast steel, carefully machined all over to uniform thicknesses; the rolling curves should be machined and finished to a dead smooth surface the pivots being forced into the bearing plates by hydraulic pressure; if it be found that the faces of the pivots were not parallel with the bed-plate, then the back of the same must be re-machined.

The granite bearing stones must be recessed for about 1 to 1½ in., and the bearing surface bush axed or (which is preferable) sand rubbed, as it was advisable that there should be no inequalities in the stone to prevent a perfect bearing being obtained.

The stones should be made in about 2-ft. 6-in. lengths, and the pivots should be about 1 in. less in length. The joints for these stones should be about ¾ in., and were not to be made until after the final concrete voussoirs were filled in.

Before fixing the pivots in the stones, sheet lead, about ⅛ in. thick, should be put in the recess in the stones, and the pivots laid in and well hammered with a heavy wooden mall; after which the stones should be fixed in position, and very great care exercised in gauging the distances between the rails so as to ascertain whether the bearing of the two rails is true; any inequality in the position of the stones could be obviated by packings laid on top of the laggings.

Use of Screw Jacks for Fixing Pivots.—After all the stones were in their correct position, it would be necessary to obtain four screw jacks so as to force the pivots as close together as possible and at the same time put a certain amount of compression on the lead seatings; when this was done, 2-in. square iron or steel bars should be forced between the back of the stones and the concrete voussoirs Nos. 2 and 12, so as to prevent any movement when the screw jacks are taken away.

In Germany they used ¾-in. bolts top and bottom, placed in the joints of the stones; but by this means very little pressure was exerted, and the bolts had to be left in until concreting was finished and afterwards cut out, which was a most difficult and very expensive method of procedure. it was, in the lecturer's opinion, one of the principal reasons why there was so much deflection in the arch when the centres were struck, owing to the fact that so little pressure was put on the seatings previous to concreting in.

There was no doubt that concreting exerts a large amount of pressure on the granite blocks, especially when the concrete was made fairly dry and heavy ramming was employed; but the pressure was light as compared to that exerted by four powerful screw jacks.

After all the stones were placed in position the concrete voussoirs Nos. 1 and 13 should be filled in. The voussoirs in the centre ought to be filled in simultaneously.

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Striking Centres.—It was not necessary that the whole of the outer spandril walls should be constructed before striking the centres; but, if there were no urgent reason why the centering should be removed, it was better to let the same remain, as it acted as a staging to enable the masons to set the stones on the spandril faces. But within three weeks after the completion of the final concrete voussoirs it was advisable to ease the centres a trifle, so as to allow a moderate amount of pressure to be exerted on the pivots; where screw jacks were used this could be easily done without in any way setting up vibration in the arch such as takes place when folding wedges are used.

Roadway.—After the centres were finally struck the concrete over the arch, forming the roadway and footway, might be filled in, care being taken to make an expansion joint over the pivots in the centre of the span and also at the springing pivots. In this country a joint ½ in. was sufficient at the centre, and the same could be made with soft felt; but at the springings, if the concrete be put in in cold weather, fully ½ in. must be allowed. In forming the roadway, whether of wood paving, granite pitching, asphalt, or macadam, the expansion joint might be ignored, though one must be put in on the footways, especially if the same were made of York paving or concrete.

In order to allow the arch to expand, the outer spandril faces must not be bonded to the abutments or piers, but be recessed into the same so as to allow perfect freedom of action; this also applied to the parapet and cornice, because, if securely fixed, an accident was bound to happen in winter if the bridge were completed in summer, and *vice versa*.

The lecturer then described some tests on a model bridge of 150-ft. span to a scale of ½ in. to the foot, and then described a few of the principal concrete bridges that have been erected abroad, commencing with the Coulouvrenière Bridge across the Rhone at Geneva. These were illustrated by means of lantern slides. Finally, the lecturer made extended remarks on the making of concrete and the proper proportions that ought to be used for different kinds of work. The results of many tests and experiments on concrete carried out by the lecturer formed addenda to the paper.

The Chairman then called upon Professor Adams to open the discussion.

PROFESSOR HENRY ADAMS, M.Inst.C.E.

Foundations. — Professor Adams referred to the statement that engineers had only considered concrete good enough for retaining walls and foundations, and of the concrete being made in the proportion of 4 to 1 for foundations. Engineers could not, as a rule, afford to put concrete of such value except in certain cases where the foundations were very thin and spread out and reinforced with metal.

With regard to concrete being able to carry with perfect safety 100 tons per sq. ft., although it had only had to carry 2 to 2½ tons per sq. ft., it should be remembered that the intensity load was on the top, and that the spread must suit the soil below, which, of course, must always be very much less.

Pivoted Arches.—Speaking of pivoted arches, which were theoretically and practically the only form of plain concrete arches that ought to be constructed; this, of course, applied where rolling loads were carried, which gave lopsided curve of thrust when the load was over one of the haunches, and the pivoting practically eliminated that difficulty. The author mentioned the centre third of the arch as the part where the curve of equilibrium should be contained. He did not mention a very common fallacy with regard to this middle third. It was commonly supposed that when any line of thrust passed within the middle third of the bearing surface, the joint was safe; the middle third only gave this result, and there was no tension on the other side of the joint. That might still be so, and yet the construction might fail from intensity of pressure, which the middle third had nothing to do with. The author had said that it was almost impossible to ascertain where the curve of equilibrium would run. That was so; but there was a natural curve of equilibrium for any condition of loading, and the shape of the arch should, as far as possible, conform to that curve. It was the inability to conform to it with a rolling load that necessitated the pivoting of the arches.

Settlement of Arches.—With regard to the settlement of arches, of course it was most important to have rigid abutments and thin joints, otherwise settlements must take place, and then an alteration in the distribution of pressure would follow. The author described one bridge where lead was used in the springing in the centre. He thought it had been practically decided by architects who had tried it, frequently in the case of stone columns made in pieces and heavily loaded, that the load was subject to a pressure that might be described as like a hydraulic pressure, which caused a spreading or sprawling of the stone at the joint. In the case mentioned, or in one of the other cases mentioned by the author, the load was kept well within the outlines of the joint, no doubt for that reason, and with probably no danger to the joint.

Figures. — Professor Adams thought Mr. Wells was a little out in his figures. The mortar in the joints, in the case of a granite arch, was one-twentieth of the crushing strength of the stone itself if made of lime, and one-fourth the strength if cement grout were used; but according to his opinion the figures for the crushing strength of granite were from 1,500 to 2,000 tons per sq. ft, whilst lime or grey mortar was only from 5 to 15 tons. The greatest stress in an arch often occurred when only half the span was loaded, unless it were pivoted. Mr. Wells had mentioned that, "If the span were loaded with 200 cwts. per sq. ft., then the maximum stress would not exceed 24 tons per sq. ft." In that place he seemed to speak of a load over the whole bridge as giving the maximum stress, but pro-

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bably half the load and half the bridge would give a greater stress, owing to the destruction of the curve of equilibrium when there was no pivoting at the ends. The settlement when the centres were struck was mentioned, and Professor Adams asked whether Mr. Wells had found any difficulty from the settlement of the arch breaking the connection with the spandril walls, as it seemed to him that that would be very likely to happen.

Useless Models.—With regard to making a model of the bridge, and testing that, of course it was very interesting in all circumstances to test a model, but personally he did not put much faith in testing models. Models, as a rule, were stronger than the structure they represented, if their strength were tested for various reasons, one alone of which it would be sufficient to mention; and that was that the linear dimensions vary directly as the scale, but the contents, the sectional area of the members, varied as the cube of the scale, so that the same proportion was not obtained in strength and size between the model and the real structure, unless allowance were made for those points. The advantages of Portland stone were very well put here, and he thought that generally was admitted to be because it was just sufficiently porous to get a good key with the cement mortar. Flint gravel and granite were not exactly too smooth, but too unabsorptive to be able to get a proper key cement.

MR. R. J. GIFFORD READ, A.M.Inst.C.E.

Various. — Mr. Read asked Mr. Wells whether nearly all the arches about which he had spoken were not reinforced concrete arches at all, but pure concrete arches made without reinforcement and pivoted. Pivoting had been very highly developed by the German engineers, and, besides allowing very flat arches to be built, was very economical. In many designs of reinforced concrete arches the general principle seemed to be to combine the arch with the abutments, and Mr. Read referred to designs in which the iron reinforcement was carried right down into the abutments and piers and there made one with the arch, so that it became a monolithic structure. He agreed with Mr. Wells that with present-day concrete there might be much higher stresses put upon it, but it had to be taken into consideration that although a test piece would stand high stress, in a large structure there was no certainty that the whole of the material in the structure was of the same character as any one particular block. Mr. Read stated that when testing some columns about 10 in. sq. and about 4 ft. 6 in. long, several of them, made with different kinds of reinforcement, and one or two without any reinforcement at all, under test, the reinforced concrete columns broke at from 230 to 300 tons per sq. ft., but the column that was not reinforced at all stood 316 tons per sq. ft. The explanation was that in a reinforced column there was a mould to make, and the iron rods had to be fixed into it, and often the iron became complicated. Thus, when ramming the columns, the ones that had the iron in them were not so easy to ram as the ones that were without iron, with the result that the concrete was not so well rammed in the former case as in the latter.

MR. PERCY TOMEY.

Reinforced and Plain Concrete.—Mr. Tomey pointed out that the question of reinforced concrete in arches had not had given to it as much attention as ordinary plain concrete. If reinforced concrete were an elastic material, then why should plain concrete with a pivot be used? It seemed advisable to reduce the thickness of the arch when the question of the extra amount of steel would not make very much difference.

MR. HERBERT BROOKS, J.P.

Bridges. —Mr. Brooks asked Mr. Wells if he had any knowledge of the results of the experiments which were recently made in Germany at the Düsseldorf Bridge. Mr. Wells probably knew that the Union of German Portland Cement Manufacturers built a bridge at the Düsseldorf Exhibition. That bridge was left until last year, when a practical test was obtained by loading up the bridge to the breaking point. At a meeting of that Union at Berlin in March, a number of views of the operations under which the bridge was broken down were shown, but the only statement made was that the factor of safety was exceeded 23½ times. The dimension of the bridge was about 30 ft. The German Concrete Union said how exceedingly glad they would be to exchange information and report upon tests with the Concrete Institute, and also exchange results of the practical tests that they were making in the various branches of concrete and reinforced concrete. They would welcome members of the Concrete Institute to their annual meetings.

MR. E. P. WELLS, J.P.

The Lecturer's Replies.—Mr. Wells dealt with retaining walls, and said in reply that he had known cases where some engineers would not use concrete for retaining walls. It was very good for foundations, but the remainder had to be in brickwork, and he thought they would find now that a large amount of retaining walls were erected which were wholly of brickwork. The only concrete used was the foundation, where it was a question of going down to a depth, and in some cases they would do as of old—build on top of the clay and not put in concrete.

With reference to a remark by Professor Adams about the lead springings in the case of the Kirchheim Bridge, Würtemburg, Mr. Wells said that lead was put in at the springings and centres. It was only put in in short lengths with a space of 3 or 4 in. between each piece of lead, so it was perfectly free to move in every direction as it came to its true bearings. But the pressure per sq. in. that was

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put upon the lead was not sufficient to cause any spreading as he had put some lead under the same pressure in the crushing machine, and found it stood it without any spreading. With a good hard lead it was safe to do it, but with one of the very soft leads, under a pressure of 1,500 to 1,600 lbs. per sq. in., it would squeeze slightly. That was the advantage of having soft lead behind pivots. It was better to have it soft ; it would come to its true bearings.

With reference to settlement in an arch breaking the connections with structural walls Mr. Wells had never known of such an instance, and it was the pivoting that prevented that. It all went bodily together. In fact, it would be possible if sufficient power could be obtained to lift one half of an arch completely off its bearings, take it off in a barge, and bring it back again and put it into position. After having been bonded on to the arch there was no chance of any accident taking place.

Regarding Portland stone concrete, there was a lot in the paper. He had experimented with that very largely 10 or 11 years ago. To get excellent concrete it was necessary to soak the stone in water first, and let it absorb as much as possible, about 10 per cent., then mix the sand and cement dry. Dump the stones into that, mix it all together, and add water as required, and the result would be an absolutely perfect concrete, so much so that if some of the rotary cement made at the present day were used in that manner in seven days, about 75 per cent. more strength would be obtained out of that concrete than out of actual stone itself. It was possible to get a greater strength out of 5 to 1 concrete made in the proportion of 4 parts to 1 of stone, 1 of sand, 1 of cement, than from the stone.

Regarding Mr. Tomey's question with reference to reinforced concrete arches, Mr. Wells thought that that was a matter that would come later on. Large span arches were especially fitted for carrying very heavy traffic, as there was almost an absolute absence of vibration. They could carry enormous loads, and architecturally were very much to be preferred. A solid arch would make a handsome bridge, whereas it was a most difficult thing to make an ordinary reinforced arch look well.

With reference to test pieces, Mr. Wells referred to the Vyrnwy Dam built by Mr. Deacon. It was stated then that the concrete was not good. Mr. Deacon went down, Mr. Wells believed, 10 or 15 ft. into the heart of the dam. The concrete was cut out. It was 6 to 1, and it then crushed at 360 tons per sq. ft., which would be a greater pressure than could have been obtained with ordinary test cubes. He believed that was on the table of the Institution 10 or 11 years ago. It was most beautiful concrete, but larger cubes always gave greater results in test than smaller cubes did, owing to the moisture remaining in the cube for a longer period.

Regarding the column about which Mr. Read had spoken, Mr. Wells knew who had made the tests. He was perfectly certain that no more cement than 1 to 5 was put there to increase its strength and he was not at all surprised that the unreinforced carried more than the reinforced.

Speaking about reinforcing the arch, and then using pivots, Mr. Wells said that while he was a great believer in the pivot, he held that it was possible to put a pivot into a reinforced arch and still further increase its strength. The pivots could be used in all sorts of stone bridges. There was one Mr. Wells had designed, 140 ft. span, the granite was only 2 ft. 6 in. in depth at the crown, and that was pivoted, and quite 75 per cent. was saved as against an ordinary stone bridge.

With reference to Mr. Brooks' statement, Mr. Wells knew nothing about the experiments at the Düsseldorf Bridge, but as Mr. Brooks had stated about 23½ times being the factor of safety he was not surprised, as that bridge was put up some years ago, and if some of the Blaubeuren cement was used he could understand getting a factor of 23½ times. Especially for their concrete bridges, the test that they got with the Blaubeuren cement, using jurassic lime stone, would, as a rule, be about 450 tons a ft. at two months old. After a number of years, taking the working stress to be about 20 or 30 tons a ft., there would be a factor of safety of 23½ to 1.

MR. ALEX. ROSS, M.Inst.C.E. (Chairman).

THE CHAIRMAN remarked that the paper had been most interesting and most valuable, and was one that could be looked at from time to time for information and reference. Mr. Wells had been rather hard on the railway engineer. As a railway engineer himself, he had used concrete for foundations, and piers of bridges and abutments of bridges, for many years. From the outward appearance he was against the face of a concrete arch abutment. It was invariably streaky, and there ensued some streaks vertical and some horizontal in all directions. He covered up his concrete by facing it with brindle or blue bricks. They would find on the heavy clay lands of the Great Northern, where the retaining walls required to be of the very best, that they are all of concrete, and had been for many years, but they were hidden up in that way. There was one thing he would like to say about arches—either brick, stone, concrete, or reinforced concrete—to the railway engineer, and to the man who had to maintain things afterwards. They were always preferable to steel or any metallic structure, where there was a constant maintenance expenditure going on, probably altogether equal to a fair interest on the capital expenditure ; and were it for no other reason than that, he would always encourage and support any means of getting structures other than metallic for all purposes of that sort.

The Chairman thereupon announced that the meeting terminated.

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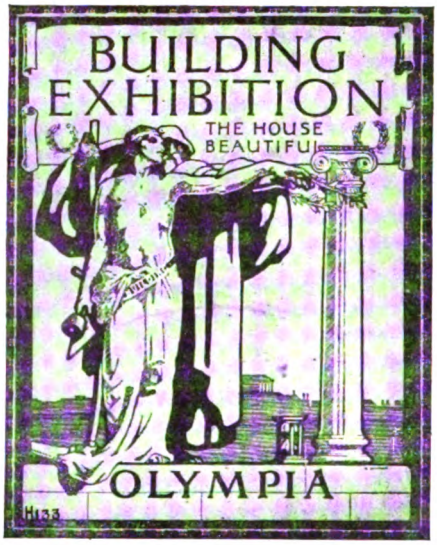

THE BUILDING TRADES EXHIBITION.

The Building Trades Exhibition at Olympia was an even greater success this year than in 1907, and must have been most instructive both to the members of the architectural and engineering professions. The Exhibition, which has become a bi-annual event of the highest importance to the building industries of Great Britain, is unique in being practically the only businesslike and comprehensive regular Building Trades Exhibition held anywhere, and far surpasses anything that has been done in this direction, either in the United States or on the Continent of Europe.—ED.

It again affords us much pleasure to give particulars of some of the exhibits of interest to our readers that were presented at this year's Building Trades Exhibition, held at Olympia, under the management of Mr. H. Greville Montgomery, M.P., and Mr. H. C. Montgomery, the Exhibition again being accorded the support it so fully deserved, both of the manufacturers and the professions concerned.

Although not inconveniently overcrowded, the great building, which is in itself a magnificent example of modern structural working, was entirely filled with a most valuable and instructive collection of materials and manufactured articles, directly or indirectly affecting building and constructional work. In arrangement the Exhibition was an excellent one, and the stands showed a vast improvement upon those of former years, not only in their design, but also in the practical character of the exhibits demonstrated.

In this journal we can obviously only deal with a small section of the exhibits as relating to concrete, reinforced concrete, constructional engineering, and the allied trades, but the particulars given will afford some idea of the extensive character of the Exhibition as a whole.

It may perhaps be a matter of interest to our readers that the Concrete Institute was one of the first societies to formally visit the Exhibition on this occasion, a large party of the members (close on 100) attending at the courteous invitation of the promoters, and making a thorough inspection of the exhibits of special interest to them.

THE EXHIBITS.

Portland Cement and Plasters.

The Associated Portland Cement Manufacturers (1900), Ltd., were represented in a large pavilion in the main hall, where they displayed the various ingredients for the manufacture of their well-known brands of Portland cement. Those not familiar with the processes in vogue in a modern cement plant were able to obtain a considerable knowledge from the specimens of material in process of fabrication, and they were able to satisfy themselves that the most modern appliances are used by this firm when testing their products. Among the samples of cement exhibited, attention was directed a good deal upon the very finely ground "Ferrocrete" brand,

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which is specially recommended for reinforced concrete construction. The installation of modern cement testing apparatus, which permitted of practical crushing and tensile tests being given during the progress of the show, was an instructive feature. It is impossible to lay too much stress upon the necessity for cement testing nowadays, when so much indifferent and fictitious "Portland" cement is placed upon the market, and the mere demonstration as to how to properly make a testing piece was in itself most useful to many of the visitors. "Parian" and superfine "Keen's" cements were also represented by samples of each, and mouldings made of the latter mixed with various colouring oxides. Before leaving the stand, visitors were able to inspect some excellent photographs of various structures carried out in different parts of the world, in which the A.P.C.M. brands had been applied. There was also an excellent model of Messrs. Stamm's Krupp ball mill on the stand. These mills are used for carrying out the preliminary grinding of Portland cement clinker, and the tube mill for the finishing grinding.

The *Wouldham Cement Co.* and the *Saxon Portland Cement Co.* were amongst the other makers represented. Both these firms exhibited samples of their products, and the former had a somewhat extensive and interesting display of cement mouldings, etc.

Other cementitious materials were represented, as the following notes show :—

Clark & Co. exhibited samples of work executed in "Xelite" plaster. The makers state that one material only is required for both rendering and finishing.

The Coatostone Decoration Co. showed samples in various methods of application in their composition, which is made in all tints, and can be applied so as to give an appearance of natural stone.

John Daymond & Son had on view some fibrous plaster enrichments for ceiling and cornices, together with useful models of plaster groined ceilings.

The Granite Silicon Plaster Co., Ltd., had a nicely-arranged pavilion showing the use of their plaster, externally, as applied to partitions.

The Gypsum Mines, Ltd., housed their cement and plaster in a pavilion built in "Sirapite," and showed productions of their minerals quarried from their Sussex and Derbyshire mines. "Sirapite" plaster can, it is stated, be applied with equal facility to wood and metal lathing.

Concrete Aggregates.

Aggregates for the preparation of concrete might have had more attention paid to them. Very few samples were shown, and sand was for some reason or other shelved entirely. Broken stone was shown by several firms, amongst whom we may mention : *The Tilbury Contracting and Dredging Co., Ltd.*, broken Kentish ragstone and chips ; *Field & Mackay*, broken basalt ; *The Clee Hill Granite Co., Ltd.*, broken basalt and chips ; *The Clee Hill Dhu Stone Co.*, machine-broken stone and basalt ; *John Freeman, Sons, & Co., Ltd.*, Cornish broken granite and chips ; *The Enderby and Stoney Stanton Granite Co., Ltd.*, granite chippings and screenings for footpaths, concreting work, etc. The following firms also showed samples of coke breeze, clinker, and furnace slag :—*Messrs. Frank Keep, The Towers' Adamantine Clinker, Fire and Roofing Tile Co.*

Concrete, Reinforced Concrete, and General Constructional Engineering.

The immense strides which reinforced concrete construction has made was thoroughly exemplified by the increased number of exhibits devoted to it exclusively, as compared with the Exhibition of 1907. On that occasion we wrote : 'We cannot help saying that the attention, devoted to this department was somewhat disappointing. . . ." Our remarks have evidently borne good fruit, and we desire to congratulate those firms who have come to the front and have seized this opportunity of showing the merits of their systems. Reinforced concrete should get all the publicity that it merits, and whilst we will leave no stone unturned to promote its welfare upon every possible occasion and in every possible manner, yet many opportunities are still missed by the purveyors of this material to give publicity to its advantages.

The Armoured Tubular Flooring Co., Ltd., showed a strip of reinforced concrete flooring constructed on their system. The floor was erected without the aid of centering, and constructed of concrete webs reinforced with a steel bar, and of concrete tubes fitted between webs, the whole finished with a thin layer of concrete. Other exhibits included patent steel bars used in the construction of armoured tubular floor, concrete tubes, and cuttings of reinforced concrete webs. Floors constructed on this system have been officially tested in London as to their fire resistance, and they hold a high record in this respect.

Edmond Coignet, Ltd., exhibited some very interesting models illustrating the method of reinforcement employed on the Coignet system of reinforced concrete construction. There was a model to 1 in. scale showing a retaining wall, footing post, beams, floor, and wall slabs complete, parts being stripped of the concrete bareing the reinforcement. There were other models of the frame work after different types of beams, together with a post and footing attached. As to the floor system shown, it was of a fire-resisting character as tested by the British Fire Prevention Committee on two occasions. Perhaps one of the most interesting exhibits was the model of

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the Coignet pile. This model was stripped of concrete in the centre, allowing the reinforcement to be seen. Another model showed the raft construction to the foundations of the Government Buildings in Jamaica, with post and beams supporting the ground floors. There was a good display of photographs, among which was seen a general view of the new Government Buildings in Jamaica, which are being erected on this system.

Expanded Metal Co., Ltd., erected a very interesting exhibit of reinforced concrete. This exhibit comprised reinforced concrete floors, beams, columns, stairs, dome, sewers, retaining walls, plaster partitions, and fire-resisting construction generally. An expanded steel-concrete floor 3 in. thick, in two spans of 6 ft., carried on concrete beams and columns, showed a typical example of the company's method of floor construction. The floor, which was situated 7 ft. above the Olympia floor level, was approached by a flight of concrete stairs reinforced with expanded steel, and had a clear unsupported span of about 11 ft. The four columns were carried up above this floor to support a concrete dome of 12 ft. 6 in. span. This dome was 4 in. thick, reinforced with expanded steel. Two of the company's floors have been under official British Fire Prevention Committee's fire tests, obtaining excellent results. Sections of an elliptical and a circular sewer were displayed, the former being 4 ft. by 4 ft., 3 in. thick, reinforced with expanded steel, the latter being 6 ft. (internal) diameter, 5 in. thick, reinforced with expanded steel. Apart from reinforced concrete, expanded metal is used for a large number of useful articles, such as letter, waste, and other baskets, fire, tree, and machinery guards, fencing, lockers, etc.

Empire Stone Co., Ltd., had an exhibit in the gallery, and showed besides their paving slabs and samples of "Empire Stone" dressed in various colours, also a "Siegwart" floor. This floor is constructed of hollow reinforced concrete beams placed side by side and grouted with cement. The floor requires no centering. Illustrations of work carried out in reinforced concrete, such as floors, retaining walls, strong rooms, etc., were also on view.

The Fawcett Construction Co. showed their new special joists, between which floor panels are carried. These joists are made on the latest Fawcett's system, and form the primary feature of their new "Monolithcrete" system of construction.

The Kleine Patent Fire-Resisting Flooring Syndicate, Ltd. occupied a very practically designed building for the purpose of representing floor and roof construction in hollow brick, the joints of which are reinforced with flat tension bars bedded in cement mortar, concrete also being generally used as a covering. The essential feature of the patent consists in constructing perfectly horizontal floors without any arch with ordinary rectangular bricks, which are neither keyed into each other nor have any other peculiarities of shape. Contraction or expansion of the brick slab, in which alone the reinforcement is embedded, is stated not to occur. Another advantage claimed for the system is the deadening of sound by means of the hollow brick used.

The Lewis Construction Co., Ltd., showed a system of reinforced concrete construction that requires no shuttering. The main feature is the use of dovetail corrugated sheeting, and the special development in the system is known as Ridley's. The main exhibit was a building supported on columns and beams which were made in the shops and erected in position, the slab being of 4 in. thickness, and on this was erected the walls of the building, 2 in. thickness. The walls were constructed of H irons and dovetail corrugated sheeting plastered on both sides. A reinforced concrete door 1¼ in. thick was shown in working order.

The Patent Indented Steel Bar Co., Ltd., had some instructive models, the most interesting of which was of an earthquake-proof house with separate foundations for earthquake districts. Here, also, the floor system shown was of a fire-resisting character, having obtained a favourable record in an official London fire test. Models were also shown of a retaining wall, floor, column, sewer, culvert, and building construction in which the concrete is reinforced throughout by steel bars of special section, with the object of affording an absolutely secure mechanical bond in addition to the cohesion between the concrete and the metal. An X-ray apparatus demonstrated the use of "Indented" steel bars in retaining walls, and this ingenious manner of giving ocular demonstration of reinforced concrete work was certainly one of the most attractive forms of exhibit met with at any exhibition.

Imperial Stone Co., Ltd., displayed several specimens of reinforced concrete sewer tubes and samples of their stone paving, the pipes being to large diameters.

Richard Johnson, Clapham & Morris, Ltd., of Manchester, exhibited specimens of their steel wire lattice system. This is a mesh system of reinforcement. The material is made in rolls (also sheets when necessary) up to 200 ft. long, and in convenient widths. In floor construction, this material being made in long lengths enables it to be secured at the front and rear of a building, and carried through the entire length without a break, thus forming a practically monolithic structure. All laps, ties, etc., are done away with. Some of the different meshes and photographs of various buildings were shown on the stand, including a small slab demon-

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strating the system. As a supplementary exhibit, there were numerous examples of the application of the smaller meshes for reinforcing brickwork, including some models on a large scale.

"*Sideolith*" showed "Skeleton" steel reinforcement of special design for concrete lintols, beams, floorings, steps, etc. This reinforcement is stamped out of single strips of metal or rolled sections without any loose parts to become misplaced. Sideolith hollow flooring was also shown, a piece of this flooring having been erected for purposes of demonstration.

D. G. Somerville & Co. represented, on a reduced scale, a section from one of their steel and concrete buildings erected for the National Telephone Co. The model showed steel framing with floors and roofs constructed of hollow reinforced concrete blocks. The concrete tiles shown were cast in iron moulds, and did not vary in size. This enabled the steel work to be accurately set out. The underside of the blocks forming the soffit were ready scored, so forming a key for plastering, two-coat work only being required. Another advantage is stated to be the sound-resisting qualities of this system, and the absence of centering. A large number of photographs were shown of important works carried out by this firm.

J. H. Tozer & Son, Ltd., had an exhibit of architectural pretensions demonstrating the uses of the lock woven mesh reinforcement in floors, roofs, walls, and the like. A set of columns with pedestals and entablature complete were shown in concrete, reinforced with lock woven mesh. A suspended floor and roof had also been constructed to show the application of continuous lengths of lock woven mesh. Specimens of reinforced concrete fence posts, which are used in connection with the lock woven mesh continuous fencing, were also on view.

The Trussed Concrete Steel Co., Ltd.—The most prominent feature of this exhibit was a small working model plant showing the method of manufacturing the "Kahn" trussed bar, specimens of which were distributed to visitors. A very practical exhibit was a reinforced concrete beam which enabled the visitor to see how concrete packed itself round the diagonals of the "Kahn" trussed bar at the point of juncture with the main bar. Doubt has occasionally been expressed upon this point, and the demonstration was intended to prove that no void occurred at any part of the beams. Another beam showed that trussed bars, when embedded in concrete, did not depend upon adhesion. Other interesting portions of this firm's display consisted of a gallery of photographs, sample bars of various sections manufactured, the "Ideal" pile for repair work, and model tanks showing the new method of making concrete waterproof.

United Kingdom Fireproofing Co., Ltd., had a practical stand, which consisted mainly of a reinforced concrete structure. The bottom floor consisted partly of their hollow concrete tubes and partly of their terra-cotta tubes. The top floor was constructed, in parts, of solid concrete, and in parts of concrete and terra-cotta blocks. Four different kinds of partitions were on view—viz., breeze concrete, plaster, pumice, and terra-cotta; also an expansion block of terra-cotta for nullifying the effect of expansion on concrete floors. Another exhibit comprised hollow soffit tiles, intended to obviate the condensation caused by change of temperature in premises such as electric power stations.

Partitions.

The Acton Concrete Partition Co. (1909), *Ltd.*, showed their partitions and wall slabs in an exhibit of architectural pretensions. The Acton partition is stated to lend itself to work of great height and length. The exhibit also comprised a practical example of the key obtained for plastering tiling, etc.

Horace W. Cullum & Co. had on view their "Kulm" pumice concrete partitions, which have been officially tested by the British Fire Prevention Committee, and hold a high record for fire-resistance. "Kulm" ceiling slabs, as exhibited, had also been submitted to a similar test, and found satisfactory.

The Fireproof Partition Co. had an interesting exhibit showing a wall of "reinforced brickwork." Under the system shown foundations are required under the carrying stanchions only, and a great saving is thus stated to be effected, particularly where unsuitable ground is met with, as clay, peat, or other bad foundations.

Gardel, Ltd., had a complete room erected with "Del" partitions, showing different kinds of setting coats. A special feature of the "Del" is stated to be that the setting coat adheres equally as well on their smooth-faced blocks as on those with a keyed surface. The "Del" is a solid partition of plaster, breeze, and a special chemical composition.

Fdk. Jones & Co. exhibited specimens of their patent "Hercules" partitions in gypsum-concrete and in Portland cement concrete. The exhibit more especially showed the various stages of erection and completion.

J. A. King & Co. displayed their plaster partitions in a large stand, also a concrete partition and a steel corner-piece for forming the external angles in plastering. The plaster partition has been subjected to official fire tests. These galvanised steel pieces, which are fixed with metal clips, are intended as a labour-saving device in plastering, as no screeds are stated to be required when they are used.

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Concrete Machinery, Blocks, Tiles, etc.

Ransome Ver-Mehr Machinery Co. showed their concrete mixers. The machine (which we described on pp. 398-9 of our November, 1908, issue) consists of a drum resting on rollers, and rotated by external spur-gearing. To the periphery of the drum, on its interior, are riveted a number of bars, criss-cross fashion. The concrete to be mixed being fed into the drum, and the latter being set in rotation, the materials are lifted by the bar afore-mentioned, to the top of the drum, whence they rain down to the bottom again owing to the cavity, being thoroughly mixed in the process. The interior of the mixer thus contains no moving parts whatever, and no bearings to which the cement, sand, or aggregate can gain access. The latest type of this machine is fitted with a movable feed hopper, thus obviating the use of shovels for throwing in the material to be mixed.

Stothert & Pitt, Ltd., exhibited their "Smith" patent mixer, with side-loading elevator, automatic water tank, motor, and starter. The drum is of conical form, supported and guided by a frame, which can be tilted at will to discharge. The interior of the drum is fitted with rigid blades, arranged in sets in a spiral. The drum is supplied with a dip ring at the discharge end, which prevents the wet material from running down the cone. It is fed and discharged while running. A more compact mixer shown was their No. 0 size, which only had a single driving pulley. This mixer was also described in our columns (*see* p. 401 of our November, 1908, issue).

Messrs. Sam Deards displayed "Smale's" patent rapid cement block-making machines, together with a patent mixer and a cement block cutter. The mixer is a dry and wet mixing machine. The moulds are passed to the left and right alternately, emptied and refilled, all this at the rate of about three a minute. The cost, inclusive of labour and material, is stated to work out at less than 1½d. per block.

Pentewan Development & Brick Co., Ltd., exhibited concrete building blocks, cavity walls, concrete hollow blocks, and partition and paving blocks, all of which were made from the celebrated Pentewan granite sand, samples of which were also shown. Their booth was erected with a view of showing how the various blocks could be used for building purposes.

Messrs. Matthew Wylie showed their concrete machines for making cement blocks, bricks, pipes, etc.

John Barker & Co., Ltd., at their stand, showed the Kennedy patent bending machine, solid rods for reinforced concrete and conduit tubes.

John Yates & Co., Ltd., showed samples of the Yates "Briton" pattern steel double-side tip waggons. A variety of tools, including a barrow for reinforced concrete work, made up a comprehensive exhibit.

Various Exhibits.

Exhibits not directly related to reinforced concrete construction, yet of importance where concrete or reinforced concrete is used, are referred to below :—

Messrs. Jos. F. Ebner.—The principal feature in the exhibit of this firm was the display of parquetry and wood block flooring, which showed several different methods of fixing, including the noted Hydrofuge system, of which 1,000,000 yds. sup. have been laid in the United Kingdom alone. There was also a collection of specimens of Roman mosaic and terazzo pavings, and of the various kinds of marble employed in decorative works. The whole of the floor of the stand was laid with "Ebnerite" jointless composition in various colours, which is specially adapted for laying on concrete floors.

Graves & Co., Ltd.—Graves' asphalte roofing is hand made and air dried, and is stated to be unaffected by weather, and not to crack with expansion and contraction. Buildings covered over thirty years ago are stated to be still in perfect condition, and the makers consider the roofing steadily improves with age, the mixture of mastic composition and sand with which it is dressed forming a permanent concrete surface, which, while being hard and firm, is capable of expansion and contraction without cracking.

F. McNeill & Co. showed their 3-ply combination roofing, which can be laid on concrete. The method is simple, and some excellent models were shown.

The Ruberoid Co., Ltd., exhibited in their pavilion a large-sized model of the roof of a house covered with "Ruberoid," which has the appearance of zinc. To a large extent the material is replacing metal, slate, or tile for roofing, more particularly in buildings of the warehouse and factory class. Where "Ruberoid" is used no metal is required, as "Ruberoid" has for its base a very durable fibrous material with great absorbent powers, by which it retains a large proportion of the saturating compound used in its manufacture. The limits of the usefulness of "Ruberoid" are not confined to roofing. "Ruberoid" flooring, for instance, was shown in use on the floor of the pavilion, and samples of "Ruberoid" damp course and felting were also exhibited.

The British Uralite Co.'s (1908), *Ltd.*, exhibit consisted of a building in imitation of old-fashioned, half-timbered work, the effect being produced by means of narrow strips of dark-coloured uralite fixed at intervals on the surface of the flat asbestos sheets forming the walls. The whole building was designed to show the adaptability of the company's manufactures

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for the construction of bungalows, cottages, etc. A dwarf partition was also shown composed of asbestos slabs, and another of uralite slabs. Uralite, it should be added, has fire-resisting qualities, as proved in official London fire tests.

Vulcanite, Ltd.'s exhibit consisted of a model which explained the application of vulcanite on a wooden roof. Vulcanite roofing consists of several layers of sheet asphalte, combined with vulcanite composition, applied in a hot liquid boiling state with a brush, making the whole roof one seamless, jointless sheet, and impervious to water. A roof of this description has been under official fire test in London. It lends itself well to flat concrete roofs, and is being applied for this purpose. Damp-course material, felting, etc., were also shown by this firm.

Generally.

Sharp, Jones & Co. displayed rock concrete roofing tiles, the feature being the interlocking of each tile with its four neighbours. There can be little doubt that with the increasing attention that is being devoted to concrete as a building material, this particular application of it will rapidly grow in public estimation.

Bath Stone Firms, Ltd., showed a representation of Bath stone mine working a section through beds of stone as now being worked 90 ft. below the surface, also a collection of specimen masonry, both monumental and architectural. Examples of Portland stone balustrading, cornices, and medallions were displayed.

Bridge, Barrett & Co. constructed and erected several stands, including those exhibited by Messrs. Sissons Bros. & Co., Messrs. Duggan Neel & McColm, Messrs. Woolliscroft & Sons, and several other minor exhibits. This firm, too, has erected buildings throughout the country in concrete.

Duggan, Neel & McColm, Ltd., had a stand which exemplified their "Dodo" enamel and flattening.

Forest of Dean Stone Firms, Ltd., exhibited samples of grey and blue Dean stone as employed for the new War Office and for the Tidsworth Barracks on Salisbury Plain, and of the Shamrock stone used in the National Gallery addition.

The Manu-Marble Co.—A complete doorway, with architraves and entablature, was shown by this firm, together with a very effective design for flooring with steps and risers in Sicilian effect.

Roadite, Ltd., made a speciality of "Ferromac," a natural road tinder used with the road metal and set with two chemical solutions. Roads so made are dustless and soundless, and afford an excellent foothold for horses. When finished the road has the appearance of light red Hampshire gravel.

There was a large exhibition of sanitary appliances, and conspicuous in this department were the stands of *Messrs. Doulton & Co.*, who showed a series of rooms, and that of *Messrs. Jennings & Co.*

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED

REINFORCED CONCRETE FOR ALUMINIUM WORKS AT KINLOCHLEVEN, N.B.

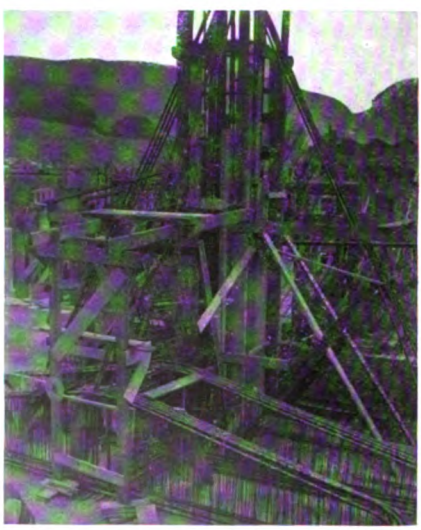
THESE new works were occasioned by the continually increasing demands for aluminium for constructional, electrical, and domestic purposes.

We are presenting only a short description of some of the structures which have been erected at Kinlochleven for The British Aluminium Company, and to which we have referred on an earlier occasion. For us the interest in the new buildings lies particularly in the fact that reinforced concrete was largely utilised.

The first aluminium furnaces were started on February 27th, 1909, by Mr. W. Murray Morrison, Technical Adviser to, and Managing Director of, the British Aluminium Co.

At Kinlochleven the general scheme consists of a large dam to form an extensive reservoir, the water from which, after a passage of 4½ miles, is delivered into the power house (probably the finest in the British Isles), which has been constructed to accommodate the necessary plant for the development of over 31,000 h.p. The other main buildings consist of aluminium and carbon factories.

Owing to the peculiar and varied nature of the sub-soil, the foundations required very careful consideration, and for the carbon factory reinforced concrete work has been used to a very large extent, both in the foundations and super-structure on account of its economy. Throughout the factory there is a large number of storage bins and bunkers, and it is interesting to note that in competitive tenders received, steel bunkers and storage bins came out to about 80 per cent. more than the estimate for same in reinforced concrete. This is partly accounted for, as every advantage has been taken of the use of local materials, and the whole of the aggregate is obtained from the local rock, which is crushed to pass the various meshes. One of the large



REINFORCED CONCRETE WORKS AT KINLOCHLEVEN.

Portion of culvert, one side reinforced concrete, one side natural rock.

Detail of reinforcement for a column, with spread foundations.

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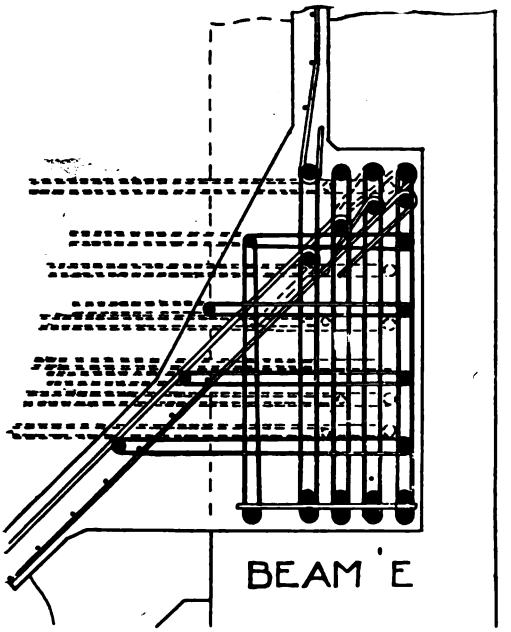

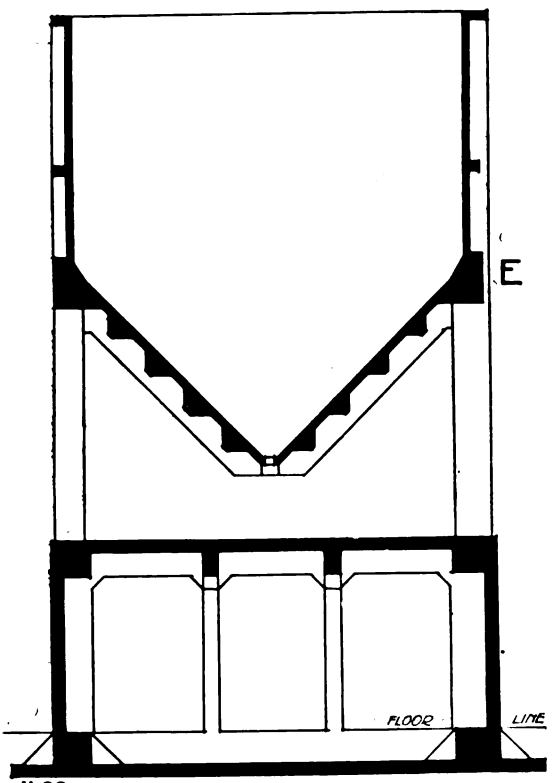

H. 99.

REINFORCED CONCRETE WORKS AT KINLOCHLEVEN.
Section of one of the bunkers and flooring, with detail of Beam E.

bunkers has a capacity of over 80,000 cub. ft., and the other bunkers are of various sizes down to 120 cub. ft. After very careful tests the aggregate decided upon was in the following proportions :—

Passed $\frac{3}{4}$ in. mesh and retained on $\frac{5}{8}$ in. mesh ...	80 parts
Passed $\frac{5}{8}$ in. mesh and retained on $\frac{1}{2}$ in. mesh ...	90 ,,
Passed $\frac{1}{2}$ in. mesh and retained on $\frac{3}{8}$ in. mesh ...	570 ,,
Passed $\frac{3}{8}$ in. mesh and retained on $\frac{1}{4}$ in. mesh ...	260 ,,
	1,000 ,,

and the sand in the following proportions :—

Passed $\frac{1}{4}$ in. mesh and retained on $\frac{1}{8}$ in. mesh ...	250 parts
Passed $\frac{1}{8}$ in. mesh and retained on $\frac{1}{16}$ in. mesh...	300 ,,
Passed $\frac{1}{16}$ in. mesh and retained on $\frac{1}{30}$ in. mesh...	200 ,,
Passed $\frac{1}{30}$ in. mesh and retained on $\frac{1}{50}$ in. mesh...	250 ,,
	1,000 ,,

The proportion of concrete (by measure) was 10 parts aggregate, 5 parts sand, 3 parts Portland cement. The cement used was the Associated Portland Cement Company's " Ferrocrete " brand. It was found that after many tests the concrete gave the following average results :—No. 1, 70 days old, crushed 4,285 lb. per sq. in.; No. 2, 56 days old, crushed 3,493 lb. per sq. in.; and No. 3, 42 days old, crushed 2,134 lbs. per sq. in.

In the case of No. 1 result the concrete was cut out from work six weeks after it had been executed, but tested seventy days after making. In the cases of Nos. 2 and 3 the concrete was taken from the mixing bunkers and made into 4-in. test cubes. The dust from the crushed stone which was not retained on 1/30-in. mesh was eliminated.

The steel used had an ultimate strength of from 60,000 lbs. to 62,000 lbs. per sq. in., and an elastic limit of not less than 50 per cent. or more than 60 per cent. of the ultimate. Through-

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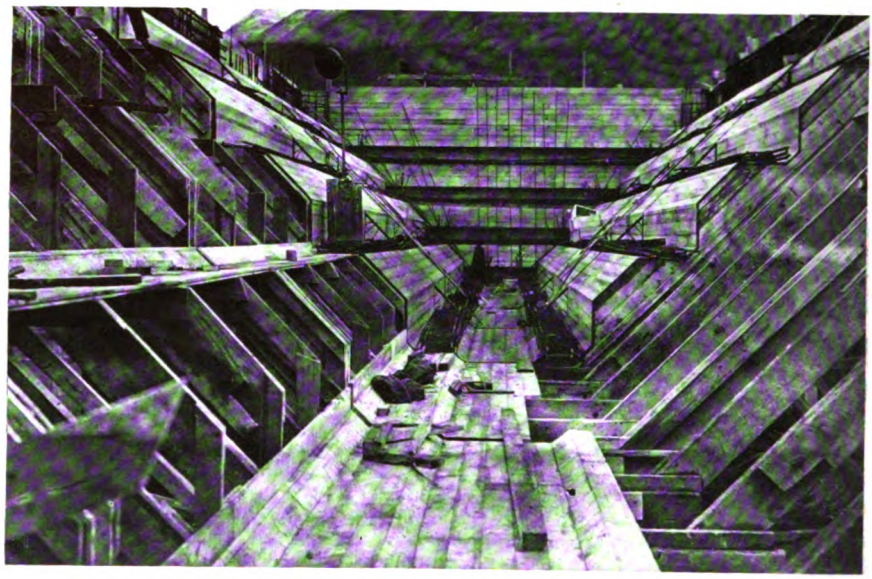
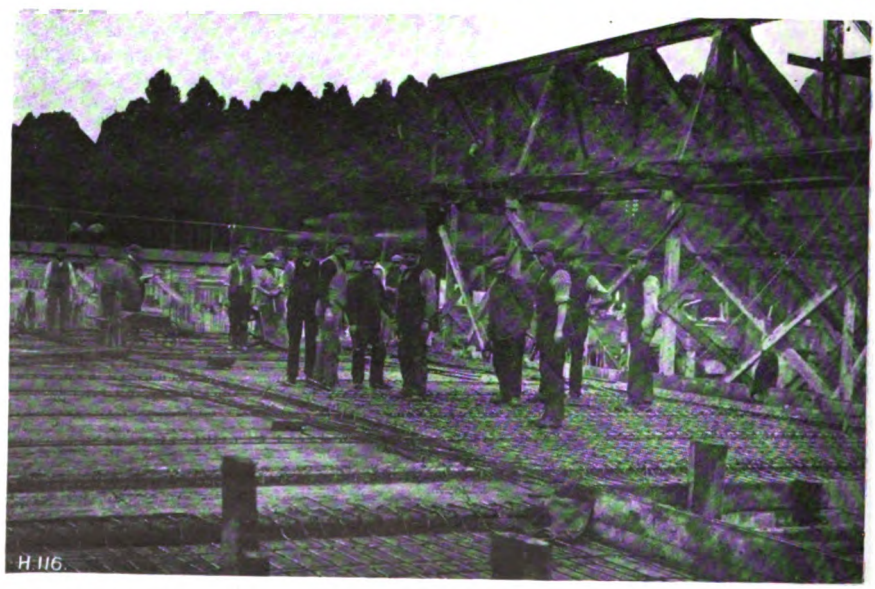
out the whole of the work no single welded joint has been used. The steel in all cases is not nearer the surface of the concrete than 2 in. in beams and 1 in. in floors, roofs,

View of centering for one of the large bunkers.





REINFORCED CONCRETE WORKS AT KINLOCHLEVEN.
Flat roof in course of construction.

and other slabs. The whole of the work was punned every 3 in. No work was allowed to be carried on when the temperature was below 34° Fahr.

The machinery, switchboard, and other galleries are constructed to carry very

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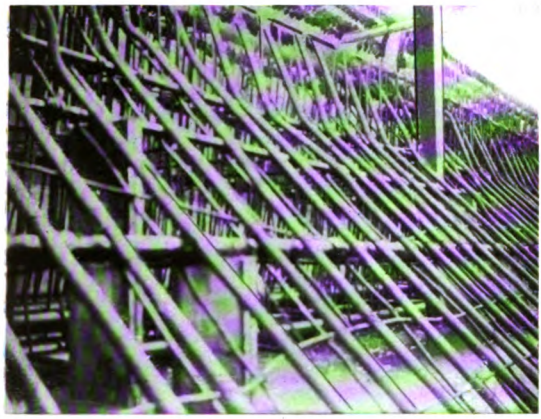
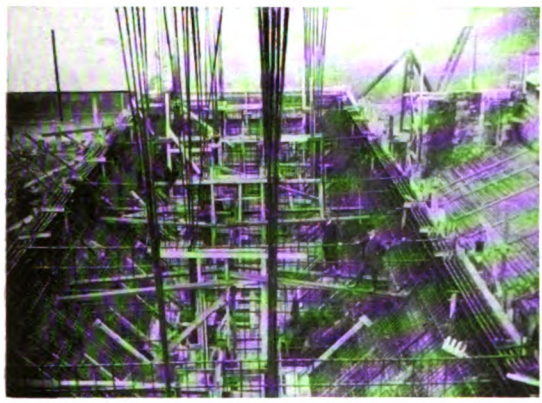
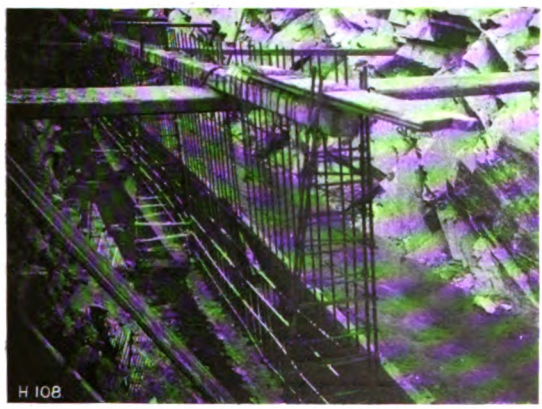
heavy weights, the principle of construction being beams and columns, all in reinforced slabs with main and subsidiary concrete. The slabs used for flooring are finished with metallic paving.







REINFORCED CONCRETE WORKS AT KINLOCHLEVEN.

1 and 2.—Views showing reinforcement for bunkers in position.
3.—Reinforcement in position for one side of culvert.

It was found to be far more economical to span all openings in stone walls with lintels of reinforced concrete, and this has been carried out not only in the factories, but also in the staff-houses, offices, etc.

The floors of the offices are also of reinforced concrete.

The testing of the cement, steel rods, and concrete cubes was carried out by Messrs. David Kirkaldy & Sons, of London.

The reinforced concrete work was executed on the Coignet system. Messrs. McLaughlin & Harvey, of Belfast and London, were the contractors for the power-house and Aluminium Factory, also for the village, staff-houses, and No. 4 Culvert, which we described and illustrated in a recent issue. Messrs. McAlpine & Sons, of Glasgow and London, were the contractors for the carbon factory.

The whole of the work has been carried out from the designs and under the superintendence of Mr. A. Alban H. Scott, M.S.A., of London, whose local representative was Mr. A. E. Bell.

REINFORCED CONCRETE BRIDGE AT THORVERTON, DEVON.

The reinforced concrete bridge at Thorverton, of which we show a photograph and a drawing, was built for the Devonshire County Council to the general design and under the supervision of Mr. S. Ingram, Surveyor for the Northern Division of the county. Mr. Hubert Berry, of Crediton, was the general contractor, while the Expanded Metal Company, Ltd., of London and West Hartlepool, designed and constructed the reinforced concrete work.

With the main arch of the old bridge still standing, as shown in the photograph, even a casual

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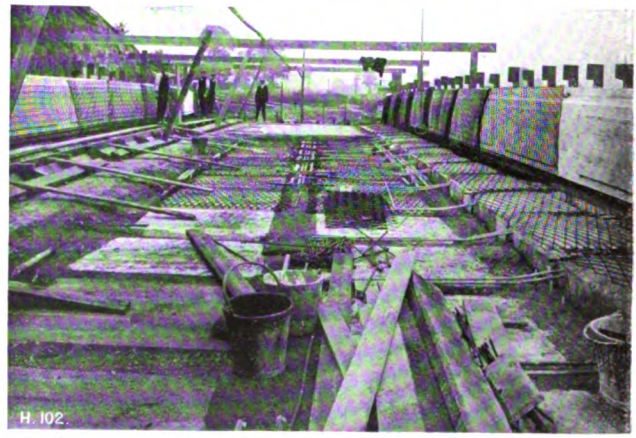
observer is able to form a comparison, which shows the superiority of modern construction over old methods. The old bridge had a considerable rise, necessitating steep approaches, whereas the rise of the new bridge is so little as to make the approaches almost level with the main road.

The new bridge was designed to carry the heaviest vehicular traffic that can pass over it, and, besides a roadway 16 ft. in width, it has two footwalks, each 4 ft. in width.

The foundations of the new bridge are 9 ft. below normal water level, and a headway of 10 ft. 6 in. is provided above the normal water level, and about 15 ft. above the river bed. The foundations stand upon a stratum of hard red marl of the old Devonian red sandstone formation, the foundation platforms, abutments, and wing walls all being monolithic with the main arch.

The detailed line drawing will give a general idea of the construction. From the section it will be seen that the foundation platforms and abutments are cellular in form, the main arch ribs supporting the cross beams carrying the bridge decking being carried through the face walls of the abutments and continued as buttresses to the main arch ribs down to the foundation platforms, the pockets or cells formed by the buttresses being filled in with stonework from the old bridge.



REINFORCED CONCRETE ROAD BRIDGE AT THORVERTON, DEVON.

The parapet walls are carried on the cantilevers supporting the footwalks, the cantilevers being a continuation of the cross beams supported by the main arch ribs.

Teign Valley chippings and the "J. B. White" Brand of Portland Cement were used for the concrete, while best British mild steel was used for the reinforcement, trussed and round bars appearing in the main arch ribs and beams, and "Expanded" Metal everywhere else.

The reinforced concrete work having been completed in November, 1908, it was duly tested in January of this year with satisfactory results. The heaviest traction-engine obtainable in the district with two large trucks full of stone were run over the bridge, while heavy concrete blocks were laid end to end along the kerb of the footpath on each side of the bridge, the deflectometers set below the bridge registering the exceptionally small deflection of three thirty-seconds of an inch at the centre of the span of the two middle ribs—the clear span being 85 ft. After this test had been made the traction-engine was run over by itself, with the result that the deflection registered at the same points was one-sixteenth of an inch. In both instances the bridge returned to its normal position when the loads had passed over.

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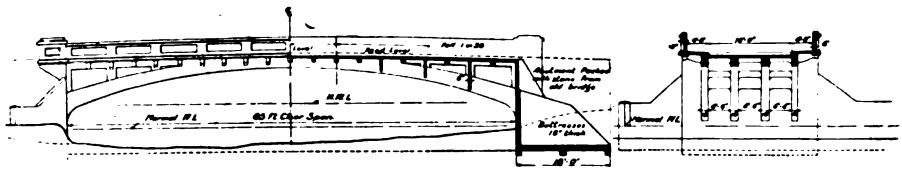
SUSPENSION BRIDGE, NEAR CARLOW, IRELAND.

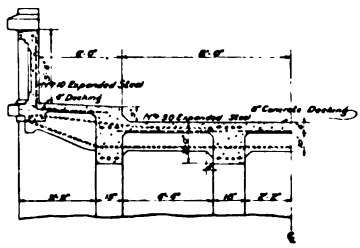
This suspension bridge is decked with concrete slabs 2 in. thick, reinforced with No. 9 " Expanded " Metal Steel, resting between 2 in. by 3 in. T's at 5 ft. centres.

The photograph presented explains itself, and the bridge affords a good example as to the application of concrete slabs with a simple reinforcement.

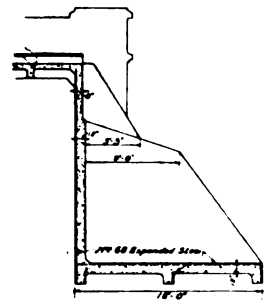


HALF ELEVATION. HALF LONGITUDINAL SECTION. CROSS SECTION THRO CROWN OF ARCH

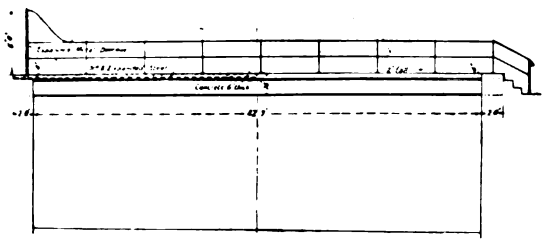
REINFORCED CONCRETE ROAD BRIDGE AT THORVERTON, DEVON.



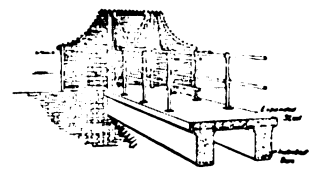
HALF CROSS SECTION AT CROWN



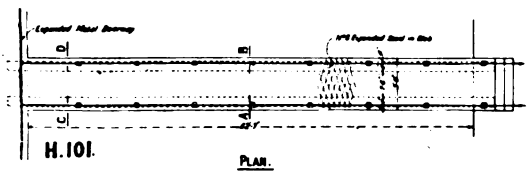
CROSS SECTION THRO ABUTMENT.



HALF LONGITUDINAL SECTION HALF ELEVATION



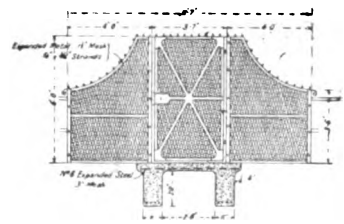
VIEW OF BRIDGE SHOWING SECTION AT A.B.



H.101.

PLAN.

— SCALE - ¼ INCH = 1 FOOT. —



SECTION AT C.D. SHOWING EXPANDED METAL DOORWAY

— SCALE ¼ INCH = 1 FOOT —

REINFORCED CONCRETE FOOTBRIDGE FOR THE HARTON COAL CO., NEAR SOUTH SHIELDS, DURHAM.

GIRDER ROAD BRIDGE AT CHOLDERTON, NEAR SALISBURY.

This small skew-span road bridge is 11 ft. clear span on the square between abutments, and 20 ft. wide between parapet walls. The decking and parapet walls are of " Expanded Steel " concrete carried by rolled steel girders.

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CONCRETE BLOCK CHURCH IN CAIRO.

Examples of concrete construction are daily growing more frequent in countries which until recently confined themselves to very primitive methods of building, and although during the last few years large blocks of buildings have been erected in Egypt in which concrete has played a considerable part, the new Church of Scotland in Cairo, opened at the beginning of this year, is, we believe, the first one in the country to be completely built of concrete blocks, and the Church Building Committee is to be congratulated on the innovation and the success it has achieved.

SUSPENSION BRIDGE, NEAR CARLOW, IRELAND.

GIRDER ROAD BRIDGE, CHOLDERTON, NEAR SALISBURY.

The following notes with respect to the building of this church are interesting. In the first place, when it was announced that the walls were intended to be only 1 ft. in thickness a certain amount of uneasiness was expressed as to the strength and heat-resisting properties of the blocks warranting walls so thin. It is satisfactory to find, however, that the strength and solidity of the building are beyond question, and that,

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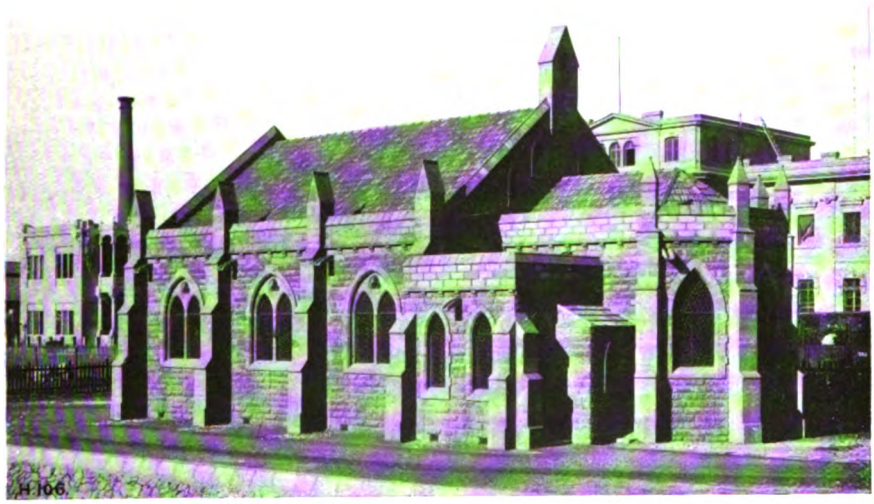
although no great heat has been experienced since the completion, it gives every indication of vindicating the heat-resisting powers of the concrete block.

The architect, Mr. W. J. Dilley, B.Sc., has been very successful in getting out a design which lends itself admirably to the nature of the material used. The main walls are of rock pitch face hollow blocks, the buttresses and parapets being solid with a plain face, and the arches and window openings decorated with a simple, but effective, moulding. The large stones for the piers of the chancel arch were made in position, and as each block set hard the mould was moved up and a fresh one formed.

The site is on the bank of a canal, and, being all made land, special attention had to be devoted to the foundations, which were carried out by M. Léon Rolin on the "Compressol" system, the earth being rammed and the concrete consolidated by large weights dropped from a height of 20 to 30 ft. by a machine of the pile-driver type.



CONCRETE BLOCK CHURCH IN CAIRO.
Exterior view.

The whole of the concrete block work was carried out by the Artificial Stone Company in situ, the hollow blocks being made on Hercules machines and the special ones in clamped wooden moulds.

All blocks were made with a facing mixture of two of sand to one of cement, the rest of the mixture being three parts of clean gravel to two of sand and one of cement. Native labour only was employed, the clerk and foreman also being Arabs, an European engineer generally supervising the work.

The building contract was obtained by an Italian firm, and the masons employed were all Italians, who carry out such work more accurately than Arabs and need less supervision.

Estimates were obtained for various types of reinforced concrete roofs, but in the end it was decided to use wood for the roof as being more decorative.

The church accommodates three hundred persons, the nave measuring 44 ft. 4 in. by 37 ft. 9 in., and the chancel 24 ft. 8 in. by 18 ft. 4 in. There is in addition a vestry 11 ft. 6 in. by 11 ft. 6 in., and a porch 10 ft. 10 in. by 8 ft. 4 in.

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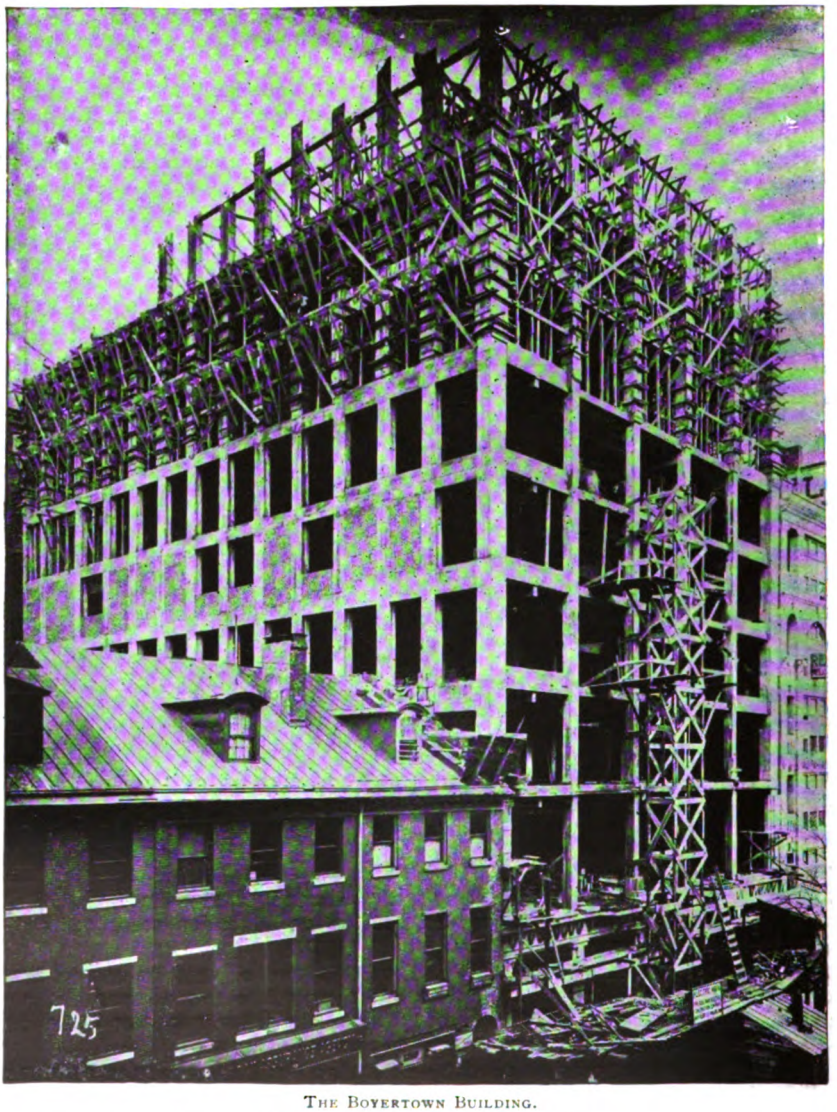
Before the use of concrete blocks for this building was suggested estimates had been laid before the Committee allowing for the thick masonry walls of the country and foundations, deeper than the bed of the canal, in the same material. By adopting the hollow block and "Compressol" foundations a considerable saving had been effected in the total cost of the work.



THE BOYERTOWN BUILDING.
(Constructed in Reinforced Concrete.)

REINFORCED CONCRETE FOR HIGH BUILDING CONSTRUCTION.

In view of the fact that there has been so much discussion as to the suitability of reinforced concrete for lofty buildings we are showing two views of the Boyertown Building, which has recently been erected in Philadelphia, and which is ten storeys in height.

The first view, of the building in course of erection, shows very plainly the

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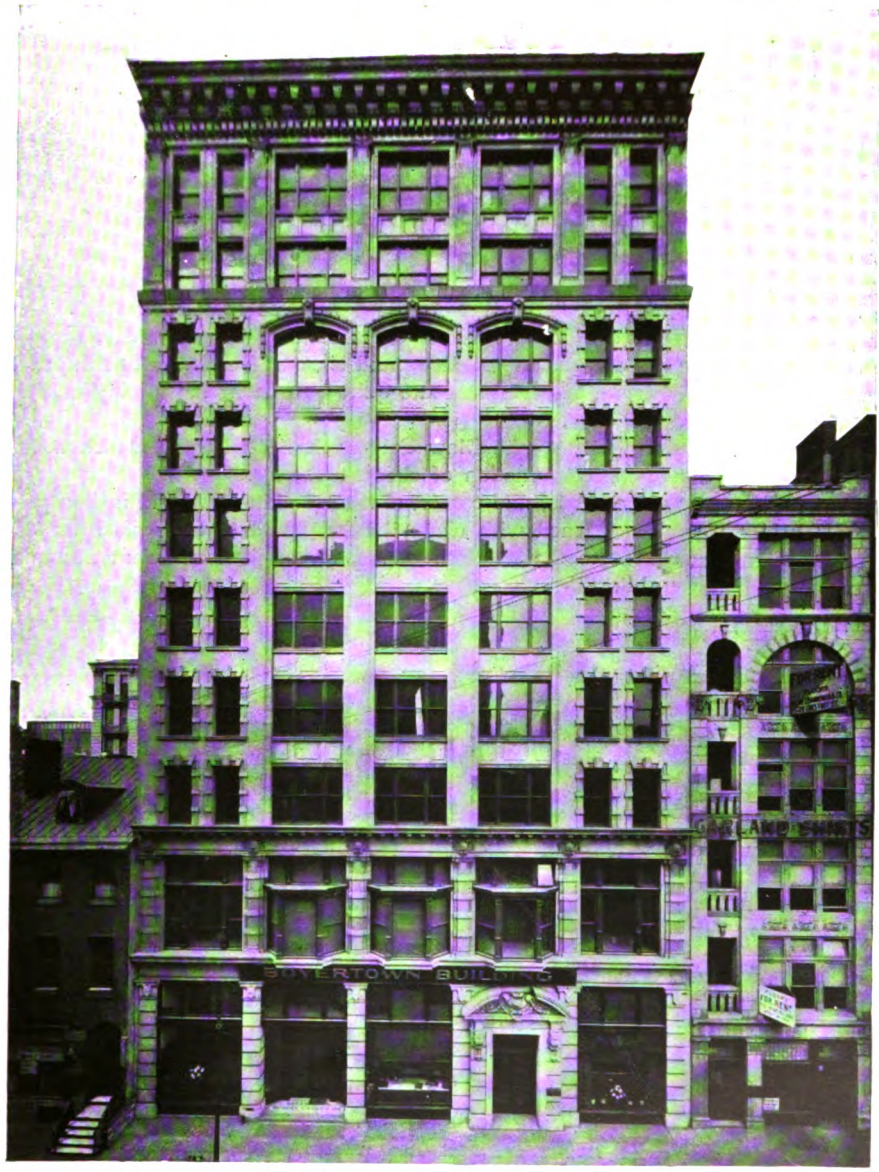
reinforced concrete steel columns without structural steel cores, reinforced with vertical bars and horizontal ties. The second view of the finished building gives the impression that the reinforced concrete has been utilised very successfully.

Provided that the design and execution of the work have every attention accorded



THE BOYERTOWN BUILDING AS COMPLETED.

them, and that the necessary precautions against fire are taken by carefully selecting the aggregate from the fire point of view, and thoroughly protecting the metal reinforcements, there seems no reason why reinforced concrete buildings of this description should not be erected on this side of the Atlantic as freely as they are in the United States.

We are indebted to the *Cement Age*, of New York, for our illustrations.

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INDUSTRIAL NOTES.

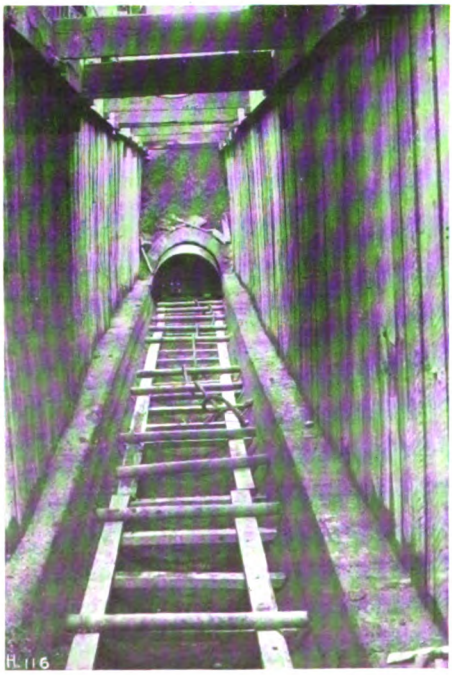
These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

STEEL CENTERING FOR CONCRETE SEWERS.

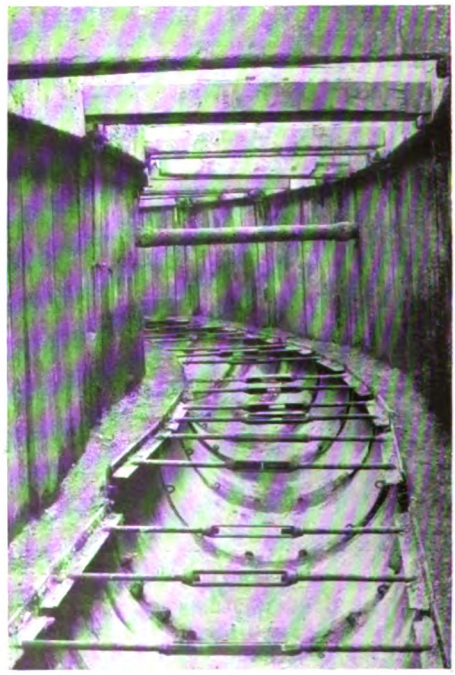
THE extraordinary increase in the use of concrete and reinforced concrete of late suggests its application to sewers and conduits more generally. Its advantages over the brick sewer are principally: Greater strength for less material; small cost of transport of materials (as in the majority of cases suitable ballast, stone, and sand can be found locally); more rapid construction; and cheaper labour, as bricklayers are dispensed with and the usual labourers become quite competent for mixing and ramming the concrete in a few days.

We give a short description of the Blaw Collapsible Steel Centre, which is likely to be adopted largely in the construction of concrete sewers.

These centres are very simple, and consist of a steel plate bent cold in heavy rolls to the proper radius and stiffened with channel bars placed at intervals around the inside, which are also bent to the required radius, although a sufficient amount of flexibility is retained to allow for collapsing.



CROWN CENTRES READY FOR PULLING FORWARD.



CENTRES IN USE ON INVERT OF CURVE.

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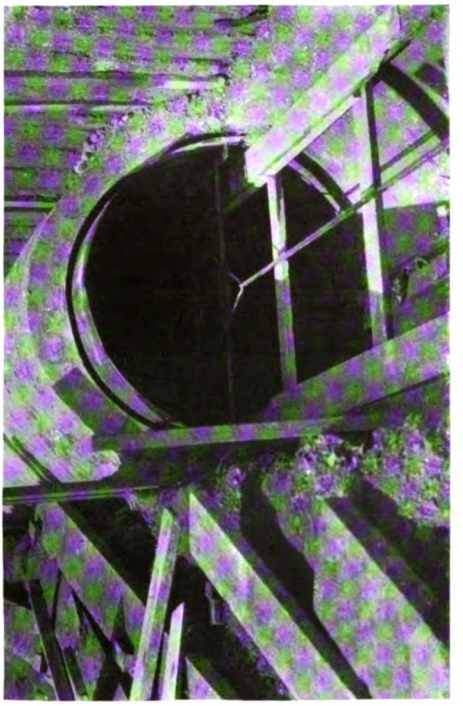
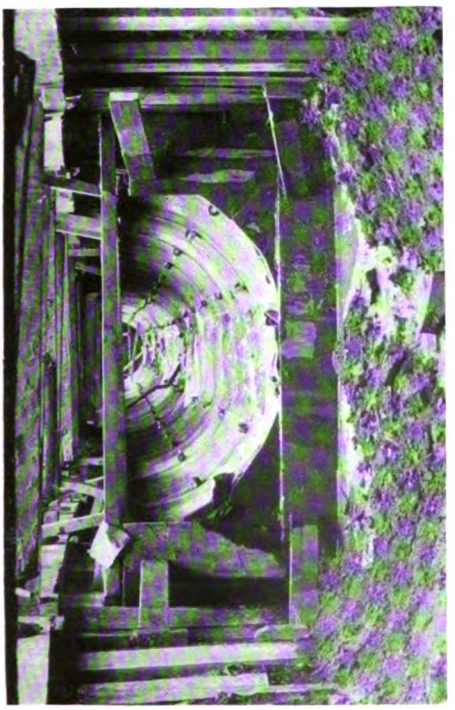
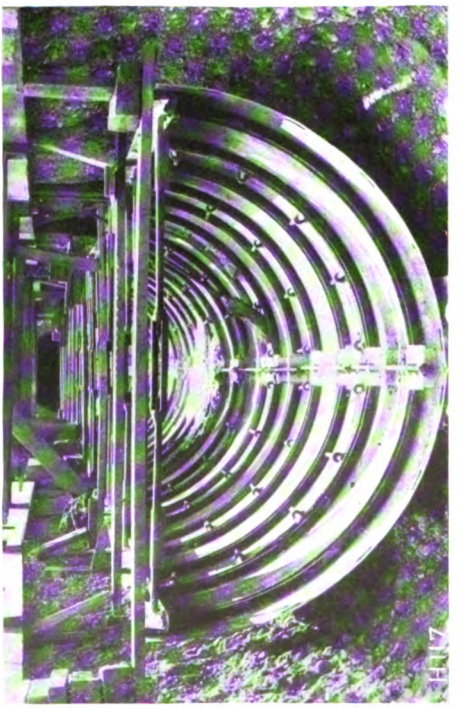
Crown Centres in Position after Concreting.



Crown Centres Collapsed ready for Pulling Forward.



Invert Concreted.



Centres in Position ready for Concreting Invert.

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Adjacent sections are held together by means of staples passing through slots in the male end of each section and secured by timber wedges. Thus a continuous smooth surface is obtained of any shape or length. The centres are held to their proper position by two tension rods at each end of the centres, to which is attachel a turn-buckle. This turn-buckle is also used for collapsing the centre. All the rivets on the outside are countersunk, so that it presents a perfectly smooth face to the concrete.

The centres are usually made in sections 5 ft. long, so that they can be easily handled by two men. The method of operating is, briefly, as follows: A dish is prepared in the trench on which the centre is placed, the concrete is run in and rammed, and after it has set the centres are collapsed by means of turn-buckles, which draw it slowly and gently away from the concrete without any jarring or hammering of any kind. After it is collapsed it is pulled along to a dish previously prepared. To construct the crown the centering is reversed and the concrete rammed. When the concrete is set the centres are collapsed and dropped to the rollers, and pulled along as a unit to the next section. In the case of large centres these are mounted on small wheels, which run on light rails. These centres can be handled so easily that 50 ft. of 5 ft. dia. centering can be collapsed, pulled forward, and set up again within an hour. To prevent the concrete adhering to the steel a cheap grease is applied.

The sewer or conduit which is constructed with these centres will be found to have an exceedingly smooth surface, as, unlike timber centering, they do not absorb any of the water from the concrete. Refinishing is therefore unnecessary, and the possibility of matter adhering to the inner surface is improbable. The centres are of ample strength to withstand the weight of the concrete without losing their shape, even when the concrete is dropped from a considerable height. The accompanying illustrations show a number of these centres of different shapes in use, and they are applicable for all kinds of conduits, culverts, mains, trenches, colliery shafts, arches, etc., whether of brick or concrete, whilst this system is also applicable for concrete pipe moulds. This form of centering will, doubtless, tend to greatly increase the popularity of concrete sewers. The invention is American, but owing to the new Patent Act the whole of the centres are manufactured in England, and it is being worked on the lease system.

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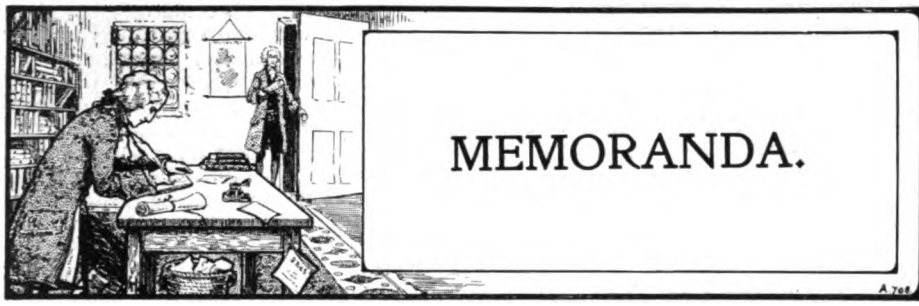

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

LECTURES.

Royal Engineers' Institute, Chatham.—Mr. J. G. Baxter, F.C.S., read an instructive paper on the present-day use of Portland cement in the manufacture of concrete before the Royal Engineers' Institute at Chatham. The paper contained a number of useful hints, and we present the following extract as a guide to users of Portland cement.

Firstly, you should see that you get pure Portland cement, complying in all respects with the requirements of the British Standard Specification. All natural and slag cements should be absolutely barred; there is not sufficient difference in price to warrant the risk. In the next place, get cement with a right setting time, and the slower the setting time in reason you can manage the better results you will get in this connection. I may say that the difference in strength of concrete made with quick and slow setting cement is inappreciable after less than 48 hours. Choose the cleanest possible aggregate and sand, and do not use anything which cannot be described as clean without making considerable experiments before doing so. Also be careful as to the water you use for mixing the concrete. Special care must be taken with the aggregate when intended for reinforced concrete work in order that nothing injurious to the steel be included. Proportion the cement, aggregate and water carefully, and see that the proportion is strictly adhered to. Also mix the cement and aggregate well before adding the water. If the work in hand warrants its use, have a concrete mixing machine, and see that it is used intelligently. Also be absolutely certain than any reinforcement is in the position it is intended to occupy.

Now as to some of the things which should not be done. Do not aerate the cement; present-day cement does not require this. Satisfy yourself that it is to British Standard Specification. If it is, use it as soon as you can; if it is not, do not have it. Don't store it in a damp place and expect it to keep indefinitely. Do not waste any time in getting the concrete into its place after water has been added, especially in hot weather; and if you are not able to get the whole batch in position before it begins to set, do not use what is left. It may be all right, but possibly it will not be. Do not mix very wet aggregate with cement and then allow it to stand for a long time before gauging. Do not take down the moulds or forms sooner than is absolutely necessary. Do not use a dry concrete for reinforced work and a wet concrete for concrete block work; the reverse is proper practice. Do not do any concrete when it is freezing if it can possibly be avoided; but, if not, get the work done as quickly as possible, and use warm water for gauging.

Finally, do not, if the cement has complied with the requirements of the British Standard Specification, blame it if anything goes wrong; in 99 cases out of a 100 it is something else.

Mr. Baxter delivered a second lecture before the Manchester Association of Students of the Institution of Civil Engineers recently, and we hope to give a full extract in our July issue.

Municipal and County Engineers.—A metropolitan district meeting of the Incorporated Association of Municipal and County Engineers was held recently at Caxton Hall, Westminster. Mr. Wm. Challoner submitted a paper on "Concrete: Its Aggregates and Mixing." He claimed that concrete, the physical properties and form of its aggregates, the methods of proportioning and mixing, might be advantageously considered, from the point of view of their practical application, as apart from that of the purely scientific standpoint of the laboratory. Whilst not intending to ignore

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the importance of the work done in the laboratory, yet such work could only be taken as an appropriate guide for the actual completed work. It was stated that the variation shown in strength of a number of test-pieces made in the laboratory approximated to variations which might occur in actual practice; but he suggested that the very extraordinary figures which were often added together to obtain an average was evidence only of some mechanical or other inconsistency in the preparation of the test-pieces. He would also limit the consideration of the coarser component parts of concrete and its mixing, without entering upon the wide field of how the building materials were made, their quality and possible admixtures, or as to whether the modern idea of reinforcement was advantageous or otherwise, except in so far as to claim in regard to reinforced concrete, as well as plain, that there could be no doubt that the advantage in either case would be to the best proportion and most perfectly distributed mixture in whatever strength might be dictated by necessity or economy.

Concrete, when in a finished condition, should be a perfectly homogeneous and fixed mass, and whatever the proportions its constituent aggregates must be equally distributed throughout the whole. This condition could not be obtained if the constituents did not in their own way go to get this result. That might be considered a very elementary principle, but it was one of those elementary principles which, though always endorsed by intention, frequently failed in actual practice. It was by no means unusual to find engineers who, without further investigation, attributed any failure or degeneracy in concrete to the cement, when probably it was entirely due to injurious elements contained in the aggregates. As to sand, he was of opinion that a little extra cost incurred in providing suitable sand would not only advantageously affect the stability of the work, but be repaid by a saving in quantity of cement. Mr. Challoner dealt at length with the means of ascertaining the proportion of voids in aggregates and the mixing of concrete, and concluded with the submission that all the elaborate and often necessary precautions exercised in the selection of Portland cement, and the most accurate and involved calculations of the engineering office and laboratory, might be rendered ineffective if the results of those were ultimately handed over to the contractor, his navvy ganger, or the navvy himself, to select the aggregate under the most casual process of supervision, and mix the concrete in the manner most suited to his convenience. Prof. H. Adams, M.Inst.C.E., who took part in the discussion, pointed out that recently clay had been regarded by some as an advantage in concrete when not in excess. But there was the question whether the fine clay would surround the cement, and they could hardly expect that the clay itself would form an adhesive compound. The grading of the material was an important matter. In the past, before they had reinforced concrete construction, the grading of the material was not thought of. He considered that it was agreed, by members of the Concrete Institute, that the measure should be by weight and not by volume, and several reasons were given for that. The practice previously had been to measure by volume, but this gave an opening for unscrupulous builders to take advantage of the property.

Public Lecture in Ireland.—A lecture was delivered in the Theatre Royal, Waterford, by Mr. J. S. E. de Vesian, M.Inst.C.E., on Reinforced Concrete Construction. The Chairman, Sir Wm. G. D. Goff, Bart., introduced the lecturer, who, in the course of his remarks, said that numerous important works embodying the joint use of concrete and steel were undertaken in other parts of the world prior to their introduction into the United Kingdom some years ago. It was well-known that lime concrete employed by the Romans had endured to our own times, and that iron embedded in the same variety of concrete had been preserved for hundreds of years without a trace of corrosion. Portland cement concrete was far more durable than the lime concrete formerly used, and there was, therefore, no doubt whatever as to the permanence of works executed in reinforced concrete in which the steel reinforcement was embedded at such depth as to preclude the possibility of injury from fire, air or water. The lecturer summed up the advantages of reinforced concrete, stating that its economy of first cost was between 10 and 25 per cent. over ordinary methods of construction; there was an entire absence of painting and costly annual upkeep charge; its durability greatly exceeded that of stone or steel; it was the most fire-resisting form of construction known, and was generally made from local materials by local labour, thereby benefiting the locality to a far greater extent than would be the case with a steel structure.

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Institution of Civil Engineers.—"Concrete and Masonry Dam Construction in New South Wales" formed the subject of discussion at the meeting of the Institution. Mr. L. A. B. Wade, M.Inst.C.E., who read the paper, showed that curved walls relying for their stability on the resistance to crushing formed a safe and economical means of storing large bodies of water. He gave instances of thirteen concrete walls, curved in plan, which had been built for the storage of town water supplies. The walls in all cases were of Portland cement concrete. The result of tests on the concrete used gave a mean crushing resistance of 50 tons per sq. ft. when mixed with soft sandstone, and 100 tons with sound igneous rocks.

Aberdeen Association of Civil Engineers.—Mr. J. W. F. Gardner, M.Inst.C.E., in the course of a lecture entitled "Notes on Cement Concrete," referred to the importance of thoroughly testing the materials employed for making concrete, and emphasised the necessity of finely-ground cement. The aggregate, consisting of sand and broken stone, ought to be as dense as possible. The advantages of wet and dry mixtures for concrete were also referred to, and the necessity for thoroughly ramming insisted on, as well as most careful inspection.

Glasgow Association.—Sir Whately Eliot, M.Inst.C.E., lectured on "The Design and Construction of Docks" before the Institution of Civil Engineers (Glasgow Association of Students). The lecturer dealt mainly with the practical work of dock construction, and pointed out the necessity of carefully examining the exact nature of the ground on which it was proposed to build a dock, as occasionally it was impossible to reach a hard foundation by ordinary means, either on account of water or excessive depth of overlying soft material.

Institution of Civil Engineers (Students).—At a students' meeting held at the Institute recently, Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., presiding, Mr. Wilfred Gurney, student, read a paper entitled "Reinforced Concrete on Railways," which was illustrated by lantern slides and several models.

Society of Chemical Industry.—To the Newcastle Section of this Society a paper was read by Mr. Chas. J. Potter on "Chemical Changes in Portland Cement Concrete and the Action of Sea Water Thereon," in which the author showed the result of practical tests he had made with regard to the changes effected in some concrete by the action of sea water. By means of these tests he had discovered that the most active cause of the trouble was magnesium sulphate—the feebly-combined lime and alumina in the cement become decomposed, forming calcium sulphate and alumina compounds, which, on taking up water on crystallisation, caused the bursting of the concrete. To counteract this action, after trial of various materials, it was found that burnt red brick clay ground with the cement when mixing gave the best results. Another set of experiments indicated the hardening action of carbon dioxide on cement concrete, and it was shown that the effect of the carbon dioxide was to replace the water and to bring about a high degree of induration.

Society of Engineers.—"A New Test for Concrete" was the subject of a paper read before the Society of Engineers by Dr. John S. Owens, A.M.Inst.C.E. In the course of his remarks Dr. Owens stated that while, in specifications for works in which concrete was used, the nature and quantity of the actual materials used were clearly specified, the quality of the resulting concrete, which depended upon thorough mixing, was not thereby assured. Thus, it was left to the engineer to satisfy himself that the mixing was being carried out efficiently, and the only methods at present available were at best very unsatisfactory. To illustrate the practical value of his method, the lecturer gave some interesting demonstrations, together with a series of experiments bearing on the evolution of the test and its accuracy. Dr. Owens concluded by expressing the hope that the test would be of value in enabling engineers to determine whether their concrete was being properly mixed or not.

Insurance Institute of Yorkshire.—A paper was read by Mr. Windsor Thorp, of Leeds, on reinforced concrete construction, and dealt with the early history and development of reinforced concrete. Great advantages were claimed for the structure of buildings properly composed of this material as compared with those in which stone, bricks, timber, exposed ironwork, etc., largely enter.

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Association of Engineers-in-Charge.—Before the members of this Association at their headquarters in Bride Lane, Fleet Street, E.C., Prof. Hy. Adams, M.Inst.C.E., read a paper on "Stresses and Strains in Girder Work," which was illustrated by lantern slides. Mr. W. H. Maw, M.Inst.C.E., presided. Through the courtesy of Messrs. Holloway Bros., the members of the Association have been permitted to view the new buildings of the G.P.O. in Newgate Street.

The Society of Architects.—Mr. D. B. Butler, A.M.Inst.C.E., F.C.S., read a most interesting paper on "The Dangers of Breeze Concrete" before this society. The subject is certainly one that merited a far larger audience than it obtained, and would have been a most suitable one to have been before the Concrete Institute or a similar society. We propose dealing with the paper at greater length in our next issue, but in the meantime we would indicate that the results were presented of a number of useful experiments, and the details were set out most precisely.

As the lecturer dealt with the German attitude in respect to coke breeze, we think it would have been well for him to have mentioned that the coke breeze generally utilised in Germany is a very different article to what we use in this country, and it may be remembered that we have already previously referred to the subject.

The following may be taken as some of the points in the lecture :—

The experiments showed that many of the specimens which indicated a marked expansion when placed under water, expanded much less than when left entirely in the air.

Taken as a whole, the experiments point to the fact that as regards the subsequent expansion, there is not much danger to be apprehended from good clean coke or clinker, or even from anthracite coal, but that some kind of ashes and furnace refuse are highly dangerous, whilst any considerable quantity of bituminous coal is fatal.

GENERAL.

Mouchel & Partners, Ltd. — In the specification for reinforced concrete, just issued by Messrs. L. G. Mouchel & Partners, Ltd., of 38, Victoria Street, S.W., a good deal of useful and instructive information is given for contractors who are desirous of tendering for works to be executed in accordance with the Hennebique system. It is a well-conceived specification and is well printed.

Contractors will be required, in the first place, to obtain their Portland cement from firms of repute, and the cement must conform with the British Standard Specification, and also comply with a special test for soundness. Added gypsum will not be allowed in any case without express permission. Concrete will have to be mixed in the proportions of (for columns, beams, floors, and the like) $4\frac{1}{2}$ cub. ft. of sand to one bag of cement (224 lbs.) with 9 cub. ft. of aggregate. For work in tidal waters and all piles—one bag of cement, $3\frac{3}{4}$ cub. ft. of sand, with $7\frac{1}{2}$ cub. ft. of aggregate. The steel will be expected to be in the form of round bars and strip. It is to be mild steel produced by the open-hearth basic or acid process. Neither Bessemer nor high-carbon steel will be allowed. The requirements for concreting are set out in detail, together with the rules for the usual tests. It is stipulated that the load tests should take place soon after hardening upon selected panels. Tests will have to be conducted upon any secondary beam in any floor, deck or roof panels selected by the engineer (or architect), and, when under full test load, no part of the construction must develop a proportionate deflection greater than 1-600th of the span.

Competition for Construction in Italian Districts subject to Earthquakes.—A public competition has been organised by the Public Works Co-operative Society of Lombardy, under the auspices of the College of Engineers and Architects of Milan, with the idea of obtaining designs and systems of construction for Government offices, country residences, and commercial buildings, which could be adopted in those districts of Italy which are most subject to earthquake shocks, the chief requirements being great stability combined with economy. The height of the buildings will be limited to 33 ft. The designs will be publicly exhibited in Milan.

Messrs. Nicholds & Reynolds, Ltd., of King's Court, Broadway, Westminster, S.W., have sent us a copy of their pamhlet describing in detail the Central Zinc Company's works at Seaton Carew, for which they contracted from designs prepared by themselves and in open competition. The buildings, which are extensive, were built entirely of steel and concrete, which method lends itself to rapidity of construction.

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CATALOGUES, ETC.

The Expanded Metal Co., Ltd., of York Mansion, S.W., have just issued a nicely-arranged pamphlet showing expanded metal lathings for plaster work. Many excellent photographs and drawings illustrate many of the buildings completed by this company.

Johnson, Clapham & Morris, Ltd., have sent us an interesting catalogue (Colonial), showing their lattice system of reinforced concrete. It is excellently got up, and contains a large amount of instructive and interesting information. Many special features are described and illustrated.

Patent Indented Steel Bar Co., Ltd.—A new catalogue for 1909 issued by this company has come to our notice, and, as in the case of earlier editions, we desire to point to the general excellence of arrangement, type, and printing. A number of illustrations have been added, and these, combined with the very useful tables and the practical hints which precede the examples, make interesting and instructive reading. Any inquiries regarding this catalogue should be addressed to the company at Queen Anne's Chambers, Westminster, S.W. This firm also, with commendable enterprise, issued their usual bulletin to coincide with the opening of the Building Trades Exhibition. Well arranged and profusely illustrated, they show many interesting examples of works recently erected with the indented bar reinforcement.

CORRECTION.

Thames Haven Jetty Head.—In describing the reconstruction of the Thames Haven Jetty Head in reinforced concrete (Considere System) in our March issue we omitted to mention the engineer's name—viz., Mr. A. E. Carey, M.Inst.C.E.

MISCELLANEOUS WANTS

CONCRETE MIXER.—Wanted to purchase at once, second-hand, a ½-yard capacity batch concrete mixer. Send full particulars, with price and present location, to Box No. 52, CONCRETE & CONSTRUCTIONAL ENGINEERING, Dewar House, Haymarket, S.W.

WANTED, in British Columbia, Canada, a CIVIL ENGINEER for FERRO-CONCRETE CONSTRUCTION WORK. One who has had experience in the making of concrete piles and general wharf work; applicants to state salary required, when available, and full particulars. 1st Class fare paid out and home at the end of engagement. Apply C. J. STEDHAM, 180 Albert Road, Southsea, Portsmouth, England.

REINFORCED CONCRETE.—A Limited Company of Engineering Specialists, working first-class patents, are open to appoint a Managing Director to take the place of one retiring for a public appointment. Excellent prospects to a skilful designer well up in the subject generally. Qualification £1,000 in shares. Only men of experience or special connection entertained. Write with full particulars of qualifications and salary expected.—Box 5385 WILLINGS, 125 Strand, W.C.

PATENT. — The proprietors of British Patent No. 23418, dated 14th November 1905, relating to process and apparatus for the manufacture of slabs of artificial stone or the like, desire to enter into arrangements by way of licence, or otherwise, on reasonable terms for the purpose of developing and practically working the same in this country. Enquiries should be addressed to W. P. THOMPSON & Co., Chartered Patent Agents, 322 High Holborn, W.C.

THE Owner of British Patent No. 2346 of 1905, entitled :—" Improvements in and relating to an Apparatus for Slaking Lime or the like to Produce Efflorescence therein." is desirous of disposing of the patent or entering into a working arrangement under license with firms likely to be interested in the same, or he would be open to consider a proposal to manufacture the invention to fill any requirements of the English market on terms to be arranged. The patent covers an invention interesting to Manufacturers of Cement-Making Plant and Cement and Lime Manufacturers. Full particulars can be obtained from and offers made (for transmission to the owner) to MARKS & CLERK, 18 Southampton Buildings, Chancery Lane, W.C.

EDITORIAL MEMOS.

CONTRIBUTIONS.—Original contributions and illustrations are specially invited from engineers, architects, surveyors, chemists, and others engaged in practical or research work. MSS. should be written on one side of the paper only, giving full name and address of the author.

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DATES OF ISSUE.—This Journal is issued bi-monthly, in January, March, May, July, September, and November. Advertisements required by 6th of month prior to subsequent issue.

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The **Triennial** Subscription is **21/-** (three years).

General Offices:
Dewar House, Haymarket, London, S.W.

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume IV. No. 3. LONDON, JULY, 1909.

EDITORIAL NOTES.

THE CONCRETE INSTITUTE.

THE Concrete Institute, the youngest of the technical bodies in London, has achieved a remarkable record ; a record which, in fact, has seldom, if ever, been equalled by any newly-formed technical society.

Although hardly a year old, it already has a membership of 750, and its initial session has been marked by progress and activity. No less than five important papers affecting concrete and reinforced concrete or their constituents have already been given by gentlemen whose words must carry weight, and the critical lens of discussion has been strongly focussed in every instance.

Altogether, the Executive of the Institute have good reason to feel proud of what has so far been achieved, and should endeavour to make still further efforts in its sphere of usefulness. To this end we are glad to note that they have already begun by arranging a summer programme of special visits. Thus, when, at this time of the year, most societies seek relaxation, the Concrete Institute will be pursuing the even tenor of its way.

These special visits were inaugurated with the recent visit to the Building Trades' Exhibition, which was followed by viewing the new General Post Office buildings in London at the invitation of Sir Henry Tanner, I.S.O., and we are sure that the forthcoming visits will not fail in interest, instruction, and usefulness.

We have been asked to mention that the Institute's offices are at No. 1 Waterloo Place, Pall Mall, to which address all communications should be sent.

REINFORCED CONCRETE VERSUS STEEL FOR BRIDGE WORK.

WHAT had almost resolved itself into a complete deadlock in connection with the proposed rebuilding of the bridge across the River Suir, at Waterford, Ireland, has apparently ended in a well-merited victory for reinforced concrete.

The existing bridge is a timber structure 832 ft. long with a draw span in the middle for the purposes of navigation. It was built by a public company in 1749, but transferred to the Waterford Corporation in 1906. Shortly after the transfer it was agreed between the corporation and the county councils of Kilkenny, Queen's County, Carlow, North and South Tipperary, Waterford, and Wexford, that the bridge should be rebuilt. Accordingly, a Viceregal Commission sat and discussed the matter, with the result that it was recommended that the new structure should take the form of a steel bridge at an estimated cost of, and total outlay not exceeding £114,000.

The contributory authorities, however, deemed this sum highly excessive,

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and it was at this stage of the proceedings that the issue assumed a broader and more interesting question from a constructional point of view.

Reinforced concrete was suggested as being particularly suitable and far more superior as regards maintenance than steel. Moreover, the cost would be reduced considerably. A public meeting was held, and it was unanimously decided to appeal to the Privy Council for the holding of an inquiry with a view of substituting a reinforced concrete bridge for the proposed steel structure.

In April last the objecting councils appeared before the Judicial Committee of the Irish Privy Council with evidence showing that a stable and perfect bridge could be constructed in reinforced concrete for £43,000. It was further explained that the cost of maintaining a steel bridge would be, at least, £800 per annum, whilst the reinforced concrete structure could be kept in perfect repair for about £100 yearly. The Judicial Committee thereupon approved the substitution of the new method of construction, subject to the submission of plans and specifications at their next meeting.

During the interregnum a violent campaign was commenced by a local paper against this decision, and letters appeared vehemently protesting against the adoption of reinforced concrete as being unsuitable and "still in an experimental stage." When it is said that at Waterford there are several important works in reinforced concrete, including a highway viaduct 700 ft. in length along the north bank of the river, a harbour breakwater at Passage East, one or two large wharves and various other industrial buildings, it can easily be seen what ignorance was being displayed even as to local affairs when these foolish statements were published as to reinforced concrete being still an experiment.

Nevertheless, the campaign was carried on to such an alarming extent that it almost succeeded in obtaining the desired effect. Those members of the Waterford Corporation who had favoured reinforced concrete were seized with fear, and actually asked the Judicial Committee to reverse its previous decision and to confirm the recommendations of the Viceregal Commissioners in favour of a steel bridge.

Every possible argument was put forward against the use of reinforced concrete, amongst them the suggestion that the conditions to be complied with were of too onerous a character to be met in the new material. One would really imagine that some of the witnesses had not heard of the very much larger reinforced concrete bridges erected under far more onerous conditions.

On June 15th the adjourned meeting of the Judicial Committee of the Privy Council was held for the purpose of examining the plans and specifications appertaining to the erection of the bridge in reinforced concrete. A large array of counsel attended on behalf of the authorities interested, but only one apparently—i.e., representing Waterford—entered a strong plea that the idea of a reinforced concrete bridge should be abandoned in favour of the original suggestion.

The commissioners, however, were not influenced by the extraordinary arguments put forward. They examined the plans and specifications, and in the end definitely approved of the construction of a reinforced concrete bridge, only giving power to the representatives of the corporation to examine the

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plans and specifications sent in, their objections, if any, to such plans and specifications to be sent to the committee within a fortnight.

Thus, for all practical purposes, final judgment has already been pronounced in favour of a reinforced concrete structure.

REINFORCED CONCRETE BRIDGES IN THE STATES.

MR. A. N. JOHNSON, the State Railway Engineer, of Illinois, U.S.A., has presented a report to the Illinois Highway Commission dealing particularly with small span bridges which constitute by far the larger proportion of all bridges constructed, and at present involve much expenditure for their maintenance. Mr. Johnson was of opinion that "practically all the money spent to-day was for bridge maintenance rather than for the construction of new bridges, including under maintenance renewals of bridges which have become useless. If, therefore, some plan could be devised by which this present constant maintenance expense could be avoided, it should receive earnest and immediate attention."

Mr. Johnson proceeds thus:—

> "After a careful study and actual experience with conditions in all parts of the State, it is recommended that all bridges of 50 ft. span or less should be constructed of concrete or reinforced concrete, as this is the most permanent form of construction known to engineers to-day."

So strongly do the authorities feel on this question that the proposal has gone forward that all bridges in Illinois of 50 ft. or smaller span should be replaced within one or two years by reinforced concrete structures.

The Report continues:—

> "The result would be the cancelling of the greater portion of the bridge tax that the townships are now called upon to pay, and the money now apportioned for bridge maintenance would in most cases be ample to pay the interest and sinking fund on the bonds. From the fact that the structures that would be built are of such a permanent character, it is in every way just that the cost should be distributed over a number of years, and would entirely justify bonds running for at least twenty-five years."

We recommend this report to those railway engineers in this country who are still of opinion that "reinforced concrete is still an experiment," and to those who are wont to croak at the non-durability of reinforced concrete bridges on account of the possible adverse effects of vibration.

THE DANGERS OF BELGIAN NATURAL CEMENT.

WE have on various occasions commented in these notes upon the practice of the vendors of Belgian natural cement who use the terms "Portland cement" and "best Portland cement" in describing their inferior wares. These tactics have been pursued not only in the United Kingdom, but also in Germany, and in the latter country the practice has been challenged in the Courts, with results which we set out below.

Before dealing with this, however, it may be interesting to reproduce a letter written by a Belgian firm in Antwerp to one of our subscribers, from whom we have received it. It appears that the Belgian firm wrote to a well-known merchant house in London offering "Portland cement of first quality" at the usual tempting prices. The merchants, suspecting the true nature of the material, wrote to the Antwerp house asking whether it was a natural or an artificial cement. Receiving in reply an admission that it was

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natural cement, the English firm wrote again expressing a doubt whether such a material ought to be described as "Portland cement," and an opinion that under no circumstances ought it to be called "first quality Portland cement." This correspondence brought a further letter from Antwerp, which we reproduce (without names) :—

"In reply to your favour of the 2nd inst. kindly allow us to say that you seem not to be in the line of our article. Indeed, natural cement is called Portland cement as well as the artificial cement, the name of Portland having been given to the natural because the cement stones were found first near Portland, in England. The imitation by artificial manufacturing only came later on. It is by exceptions that the artificial product is better than the natural, it generally being the contrary [*sic*].

"All the Belgian cement manufactories wear the name of Portland cement manufacturers, and if we call our cement 'first quality' it is because there are four qualities following the tensile strain. Moreover, this quality is sold everywhere in the world as Portland, and goes in large quantities to the English colonies, and South America takes hundred thousands casks of it. Everybody who is in the trade knows what it is, and more than hundred thousand tons are used in your country as Portland cement. You might have heard of brands like * . . . . . etc. Well, they are nothing else but the same quality we sell. Even in Germany, where the manufacturers have done their utmost by legal proceedings to force the Belgian, who are supplying more than 100,000 tons a year in Germany, to renounce to the name of 'Portland,' the question has been decided in favour of our manufacturers."

The ignorance of the real facts which this letter displays is only matched by the hardihood of the assertions it contains. The unreliability of natural cement is so unfavourably known that there is no need to dwell on that aspect of the misstatements. As to the quantity of natural cement that reaches our Colonies, it is fortunately decreasing, as can be seen from the official returns. As to the historical aspect, we would, however, remind our readers that the natural cement in use prior to the invention of Portland cement was known as Roman cement, and the name "Portland cement" was the title selected by Aspdin, its inventor, and given to the artificial mixture of limestone and clay, which was found to yield a product resembling Portland stone in *colour*. In other words, the term "Portland cement" was *not* given to the natural product, and it was *not* discovered or invented near Portland, in England.

THE GERMAN FIGHT AGAINST BELGIAN NATURAL CEMENT.

Turning now to the assertion with which the Belgian letter concludes—namely, the trade description of natural cement in Germany—we give a translation of an article on this subject which appeared in the *Tonindustrie Zeitung*, of Berlin, published on May 15th last :

"In the matter of the prosecution entered by the Rhenish Westphalian Cement Syndicate against different merchants dealing in Belgian cement on the ground of unfair competition, the Superior Provincial Court in Dusseldorf has confirmed the judgment of the Court of First Instance, according to which these dealers were forbidden to make use of the terms 'Portland cement' and 'best Portland cement' in public recommendations, circulars or circular letters when describing the natural cement in which they deal.

"According to the terms of the judgment, the question whether an improper statement and an exceptionally favourable offer has, in fact, been made, depends upon the view taken of it in those circles of customers for whom the circular issued by the defendant was intended. The opinions obtained went to show that in trade circles an artificially mixed product was always understood by the term 'Portland cement.' By the admission of the defendant it was established that in the circular he wished to recommend Belgian natural cement ; but if he offered this under the description of Portland cement he made an unfair statement about the method of its production. Also, the further verdict of the Lower Court that the incorrect statement was designed to create the appearance of an exceptionally favourable offer could be unconditionally confirmed.

* Two brands of Belgian Natural Cement are here mentioned.

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The definition of 'offer' must by no means be understood here as synonymous only with that of a definite offer capable of acceptance, but embraces every sort of invitation to purchase or otherwise take the material. The Court withdraws itself from any definite determination of the question whether, during the further course of the business negotiations (the commencement of which was brought about by the circular), and prior to the conclusion of the contract every purchaser was made acquainted with the actual circumstances. It does not in any way depend on this, because unfair competition is already complete with the issue of the circular, and not merely when a contract has been concluded owing to a misunderstanding on the part of the buyer. The purchaser has already been tempted thereby to the disadvantage of honest competition, because the circular makes it appear that a specially favourable opportunity of purchase is offered. As the defendant offered Belgian natural cement as 'best Portland cement of exceptional quality and at exceptionally cheap prices,' he influenced the judgment of the buyer concerning the quality and cheapness of his goods to the injury of honest competition, even though in certain cases the cement which he offered might really be equal to Portland cement. The judgment which, on security being given for costs, was declared to be immediately effective, offers to the syndicate a valuable weapon in its fight against the Belgian cement."

FIRE PREVENTION AND CONCRETE.

THE British Fire Prevention Committee has recently been the subject of a considerable amount of favourable comment in the technical Press on the occasion of its tenth anniversary of incorporation.

We would take this opportunity of pointing to the fact that it has been mainly due to the research work of that Committee that concrete floors nowadays largely take the place of the hollow floors of dense terracotta which used to be so much in vogue, and, further, that reinforced concrete was accorded full confidence as a fire-resisting material in our public buildings. The research work of the Committee in the direction of concrete and reinforced concrete from the fire point of view has been the most extensive of its kind undertaken anywhere, and the records presented have been most useful for reference purposes on account of their only containing facts without critical commentary.

The Committee is now occupied with the question of concrete aggregates, not only from the fire point of view, but from the more general aspect, and we are glad to note that the proposals of the Committee as to a series of tests in this direction have been receiving the support of our public departments.

CONCRETE AS A FIRE RESISTANT.

A BULLETIN describing the fire-resistive qualities of building materials will be issued within a short time by the United States Geological Survey. Some particulars as to the tests undertaken have already been dealt with in our November issue. Various materials used in building were subjected to the direct application of heat for two hours in the laboratories of the National Board of Fire Underwriters, in Chicago, high temperatures being reached. After being exposed to the fire the materials were withdrawn from the furnace, and water was applied in order to get the conditions that would obtain after the firemen had begun their work on a burning building.

The investigations were conducted under the direction of Mr. Richard L. Humphrey, engineer in charge of the structural materials laboratory of the Survey. The investigations had the object of lessening the liability of loss by fire in American Government buildings which are not insured.

Mr. Humphrey, we understand, has now given the following expression of personal opinion on the tests. He is stated to have said :—

"The fact brought out most clearly by these tests is the low rate of heat transmission of Portland cement concretes and mortars. This is one of the desirable qualities in buildings intended for 'fireproofing' purposes."

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"For marking the cement blocks, linen tags were fastened by wire nails to the interior walls at the time of moulding. Most of these tags remained in place during the test, and when the walls were demolished the tags in every case were found entirely undamaged."

"An average of all the tests shows that about 90 per cent. of the maximum temperatures attained by the faces of the panels were reached in one hour, while in the case of the mortar blocks the increase in temperature of the backs of the panels in one hour was only about 20 per cent. of the total increase in the two hours. Of the solid concrete panels, the cinder concrete showed the smallest increase in the temperatures of the backs of the walls, and the granite concrete the largest. The total increase in the temperatures of the mortar panels was about the same as the total increase in the temperatures of the backs of the concrete, but the increase in one hour was somewhat greater in the case of the concrete."

"The damage done to the faces of the mortar and concrete panels would probably be caused at a temperature about half that of the maximum temperatures reached, owing to the water of crystallisation being driven from the mortar. This thin layer of dehydrated mortar may have formed a protective coating and prevented dehydration."

"It was noticeable that the richer the mortars used in these blocks the better they withstood the tests. The amount of water used in mixing the mortars had a similar effect on the fire-resistive qualities; the mortars mixed with the greatest percentage of water gave the best results."

"When the blocks were cracked or spalled before the application of water, the damage appeared to be greater in the dry mixtures containing the greatest percentage of sand, and it was further observed during the fire test that the richer mixtures warmed up more slowly than the others. It is apparent that one of the causes of weakness in the cement hollow building blocks under these fire tests was the weakness of the concrete, a too dry and lean mixture, which, coupled with the thinness of the webs, provided insufficient strength to resist the stress due to the rapid expansion of the face. It is quite possible, as was shown in some of the block tests, to make blocks which will pass the conditions perfectly; the web must be thick enough to give the necessary strength."

"The concrete behaved remarkably well, and it was difficult to determine whether the limestone, granite, gravel, or cinder concrete sustained the least damage. The faces of all the panels were more or less pitted by the fire and washed away by the stream of water. The test was unfair to the cinder concrete, as the cinder was very poor, containing a large percentage of unburned coal. However, the sample selected was the best of six or eight investigated in St. Louis. During the fire test the coal ignited and left the surface of the concrete very rough and badly pitted. The limestone aggregate in the face calcined, and the granite aggregate split and broke away from the surface mortar. The granite concrete probably behaved better than any of the above-mentioned concretes. Damage in no case extended deeply, probably not more than 1½ inches. The evidence shows that even at this depth the temperature was comparatively low. The high stresses produced in the panels by the rapid rise of the temperatures of the faces, while the backs remained cool, caused cracks. On taking down the panels the blocks of concrete were found to be cracked vertically for some distance from the face."

Now, the views so ably put forward by Mr. Humphrey are no doubt very valuable, and deserve careful reading, but we must say that we should prefer his laboratory not to issue incomplete information, followed by expressions of personal opinion. We should prefer to see full detailed and illustrated reports published with the simple facts and records, and free from commentaries. We may agree with the deductions Mr. Humphrey presents; we may be in full accord with such of the information regarding the tests that has reached us, but a complete record of facts only would be immeasurably more useful. Detailed facts, not opinions, are what the technical professions desire. We are, however, glad to note that Mr. Humphrey's deductions are so favourable for concrete.

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PUBLIC OFFICE FACING KING EDWARD VII. STREET.

NEW GENERAL POST OFFICE BUILDINGS, ST. MARTIN'S-LE-GRAND, LONDON.

The current year marks the structural completion of the most important reinforced concrete building as yet erected in the United Kingdom—namely, the extensive additions of the General Post Office at St. Martin's-le-Grand. We have dealt with these buildings at some length in a previous issue and we now present some additional information and illustrations.—ED.

WE have from time to time referred to the excellent reinforced concrete structure that is being erected for the General Post Office extensions, and in our January issue (see Vol. III., No. 6) we dealt with some of the technical features at length.

We take opportunity of again referring to this structure, having regard to the visit of inspection paid to it by the Concrete Institute last month, when some seventy members assembled at the invitation of Sir Henry Tanner, I.S.O., F.R.I.B.A., Principal Architect at H.M. Office of Works, to whose designs the building is being carried out.

It may be remarked that the actual reinforced concrete work is on the Hennebique system, Messrs. L. G. Mouchel and Partners having acted as consulting specialists and engineers of this work, and it may also be borne in mind that the general contractors were Messrs. Holloway Bros., Ltd., that the Portland cement used was the Hilton Anderson Brand of the Associated Portland Cement Manufacturers (1909) Ltd., and that the steel rods were supplied by The Whitehead Iron and Steel Co., Ltd., Tredegar.

The party of members of the Concrete Institute was in charge of Mr. H. D. Searles-Wood, F.R.I.B.A., a member of the Executive, and they assembled in one of the offices of the building, where they were received by Sir Henry Tanner. After a minute inspection of the drawings exhibited, Sir Henry addressed the gathering on the subject of the building, and from this address the following are some of the more important extracts :—

"The points which governed the arrangement of the plan were : (1) The necessity of providing a public office next to King Edward Street ; and (2) the necessity for having roadways and platforms at either end of the Sorting Office. The division of the buildings into two blocks followed. The two lower floors occupy the whole area of both blocks *plus* that of the separating roadway, while on the second floor they are connected by a bridge."

"The buildings are constructed on the Hennibique system, and my instructions to M. Mouchel

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were: (1) That the supports were to be of the minimum area; (2) that they were to be as few as possible; (3) that the beams were to be as shallow as possible; (4) that the platforms were to be

General Post Office, Reinforced Concrete Extensions.
A General View and the Cantilever Projection of Upper Storeys.

unobstructed; (5) that there must be a bridge connecting the two buildings on an upper floor; and 6) that the factor of safety be 4."

"The plans were prepared in my office in skeleton, and M. Mouchel adapted his construction

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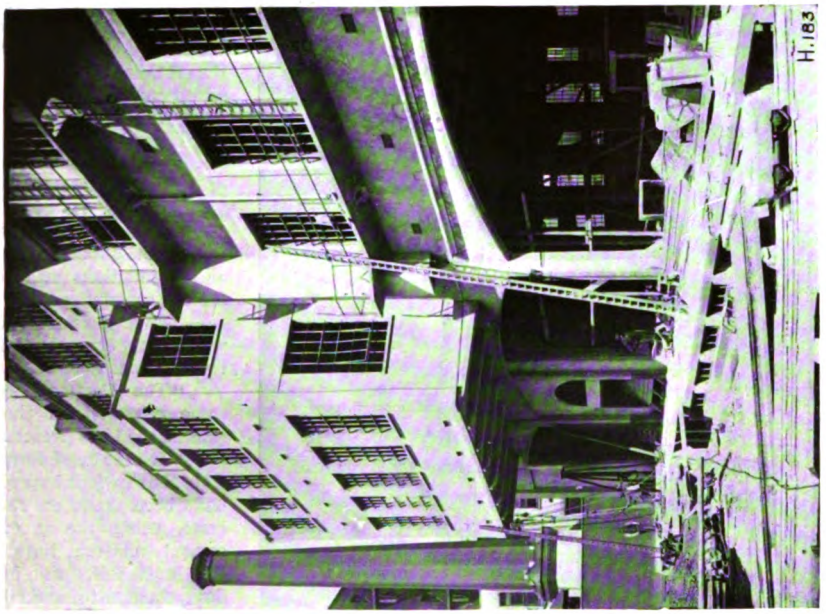
to suit them, and, as shown above, he had some interesting problems to work out. However, he proved quite equal to the task set him. The spans vary from 39 ft. to 50 ft."



General Post Office, Reinforced Concrete Extensions
View of Sorting Office and Loading Galleries.

"The loads on the ground and sub-ground floors were to be calculated at 1 cwt. per ft. super and those above at ¾ cwt., while the roadway was to be taken at 2 cwt. Portions of the floors have been loaded at from 1½ to 2½ and carried these loads satisfactorily."

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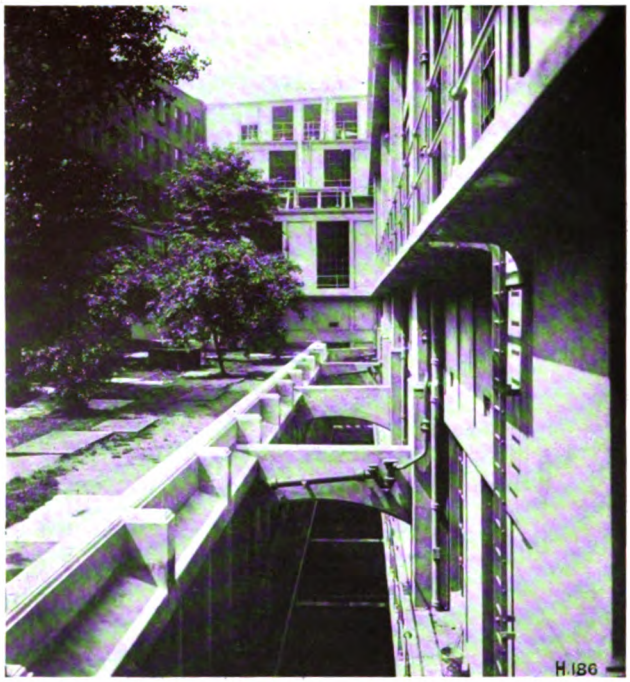

General Post Office, Reinforced Concrete Extensions.
View of a Retaining Wall.

"The steel bars have not been coated in any way. Any rust was simply removed by the use of hard wire brushes, and where the walls have had to be cut into the steel has been found quite sound and free from rust."

"The concrete is of the usual description specified by M. Mouchel—namely, 27 cu. ft. of Thames ballast crushed to ¾ in., 13½ cu. ft. of Thames sand, and 7 cwt. Portland cement for underground work and foundations and 6 cwt. for the remainder."

"So far no percolation of water has occurred through the outer walls below ground."

"The Portland cement came out well on the right side of the tests prescribed."

"It may be of interest to state that various experiments have been made on the concrete, using the 7 cwt. of cement mixture both fairly dry and wet, at fifty-six days, six months, and eighteen months. The greatest increases in strength occurred in the dry mixtures."

In conclusion we would add that the visit was much appreciated by the members of the Concrete Institute, as there was a great deal to see that was eminently instructive. Amongst those who assisted in showing the buildings to the visitors were Mr. de Vesian, M.Inst.C.E., and Mr. Gueritte (of Messrs. Mouchel and Partners), Mr. Woodward, the clerk of works, and Mr. Chapman, his assistant.

General Post Office Reinforced Concrete Extensions.
Bird's-eye View of the Reinforced Concrete Roofs and Lantern Lights.

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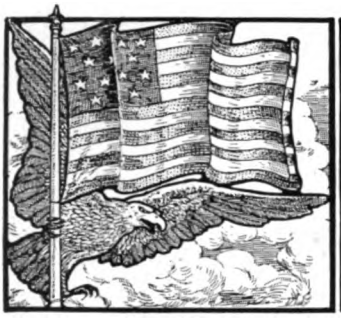

REINFORCED CONCRETE RESERVOIRS IN THE UNITED STATES.

By ERNEST R. MATTHEWS, F.R.S.Ed., F.G.S., A.M.Inst.C.E.
Borough Engineer of Bridlington.

The number of reservoirs in course of construction in the United States is considerable, and a very large number of them are in reinforced concrete. Having regard to the importance of the subject to municipal engineers in Great Britain and the Colonies, a special article on the subject is herewith presented.—ED.

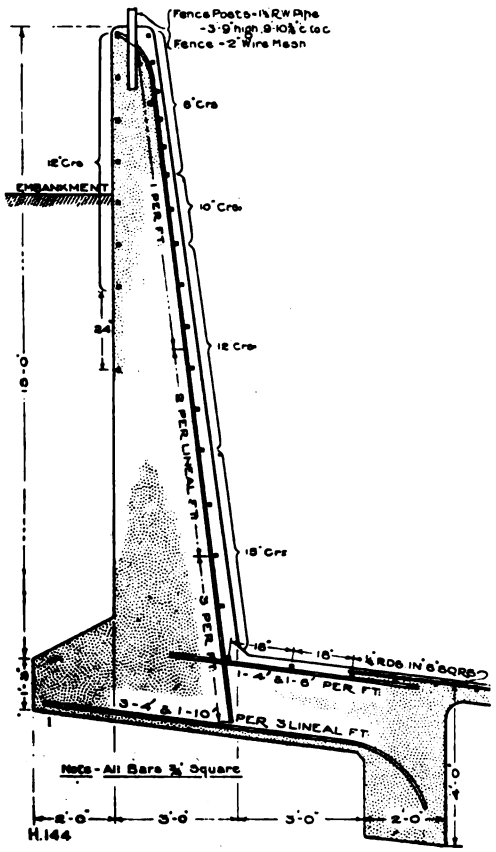

Fig. 1. Open Reservoir at Bloomington, Ill.
(See also Fig. 7.)

Waterworks engineers in the United States of America have long since realised that reinforced concrete is eminently suitable for the construction of reservoirs, and so the author was not surprised to find upon enquiry that some excellent examples of work of this class had been carried out during the past few years, and others are now being carried out, particulars of which follow. That this material should have met with such favour in the States little wonder can be expressed, for its use in reservoir construction has much to be said in its favour :—*(a)* Economy in cost. (Covered service reservoirs constructed of this material are about 15 per cent. cheaper than when constructed of plain concrete.) *(b)* The occupation of less space. *(c)* That no repairs are needed. *(d)* Its great hygienic value. *(e)* That it increases in strength with age. *(f)* The rapidity with which the work may be executed. *(g)* That reinforced concrete reservoirs have no joints.

These and other recommendations have been recognised by American engineers, and are also receiving the careful consideration of waterworks engineers in this country at the present time.

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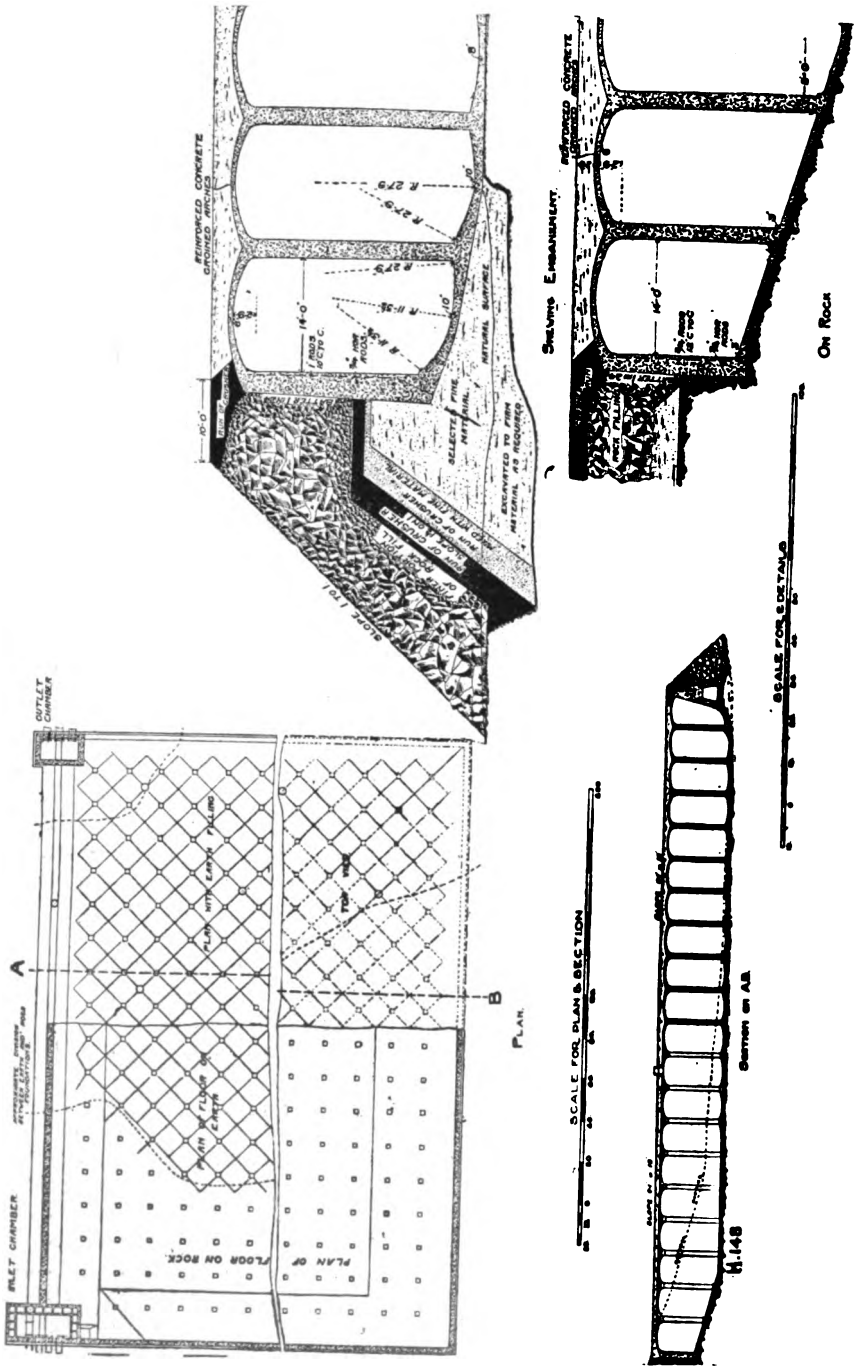

Fig. 2. The Provin Mountain Concrete Reservoir, Springfield Water Works, U.S.A.

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Before describing some typical examples of American reinforced concrete reservoirs, reference should be made to :—

(A). The concrete used in that country.
(B). Reinforcement.
(C). Design of piers in reservoirs.

(A). ***Concrete.***—What is known as " wet " concrete is used in reservoir construction in the States. This certainly requires no ramming, but it is not, in the author's opinion, so satisfactory a method as that of using it moderately wet, putting it in in layers, and well ramming each layer. Another practice that is adopted, and in the author's opinion it is an unsatisfactory one, is, to insert " plumbs " in the thin walls of reinforced concrete reservoirs. Where walls are of no greater thickness than, say, 8 in., to allow (as some American engineers do) 4 in. plumbs to be inserted, seems to be very undesirable. The proportions of the concrete used are very different from our English practice, 7 and even 8 to 1 concrete for reservoir walls and floors is a common thing, while in this country 4 to 1 is generally specified. Again, all concrete is mixed by machine.

(B). ***Reinforcement.***—With regard to the reinforcement there are many different systems in vogue, but all are designed to conform to the regulations of the various cities. In Chicago, for example, the law relating to reinforcement is as follows :—

* " *Method of Reinforcing.*—All reinforcing steel shall be completely enclosed by the concrete, and such steel shall nowhere be nearer to the surface of the concrete than the diameter of such reinforcing steel bar, or rod, or other shape. The steel in beams or girders shall be so disposed that there shall be not less than 1½ times the thickness of the steel in concrete between the steel, and, where more than two bars are used the bars shall be placed in two or more planes.

" Reinforced concrete shall be so designed that the stresses in the concrete and the steel shall not exceed the following limits : extreme fibre stress on concrete in compression, 500 lb. per sq. in. ; shearing stress in concrete, 75 lb. per sq. in. ; concrete in direct compression, 350 lb. per sq. in. ; tensile stress in steel, ⅓rd of the elastic limit ; shearing stress in steel, 10,000 lb. per sq. in.

" The adhesion of concrete to steel shall be assumed to be 75 lb. per sq. in. of surface where bars are three-quarters of an inch or less in diameter, and proportionately less for bars of a diameter greater than three-quarters of an inch.

" The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

" The following assumption shall guide in the determination of the bending moments due to external forces : beams and girders shall be considered as simply supported at the ends, no allowance being made for continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than W.L. divided by 8 ; the bending moment may be taken at W.L. divided by 20 in the case of square floor plates which are reinforced in both directions and supported on all sides. The floor plates to the extent of not more than five times the width of any beam or girder may be taken as part of that beam or girder in computing its moment of resistance.

" The moment of resistance of any reinforced concrete construction under transverse loads shall be determined by formulæ based on the following assumption :—

" (1) The bond between the concrete and steel is sufficient to make the two materials act together as a homogeneous solid.

* Clauses 549-555, pp. 106-107, Chicago Building Laws (1906).

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"(2) The strain in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

"(3) The modulus of elasticity of the concrete remains constant within the limits of the working stresses fixed in this chapter.

"From these assumptions it follows that the stress in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

"The tensile strength of the concrete shall not be considered."

Many American engineers apply a coat of cement grout to the reinforcement a few hours before the insertion of the latter into the concrete, to prevent rusting, and this seems to be most effective according to the experiments carried out by the Author, by Prof. C. L. Norton, of the Massachusetts Institute of Technology, Boston, and of others; it is a perfect safeguard against corrosion.

(C). ***Design of Piers.***—Circular reinforced piers have of late been introduced in American practice in connection with covered reservoirs, and they are advantageous because they:— (1) Occupy less space. (2) Save material over square or rectangular piers. (3) Can usually be constructed at the same price in America as square piers, alternative prices have been invited in some cases and with the result named.

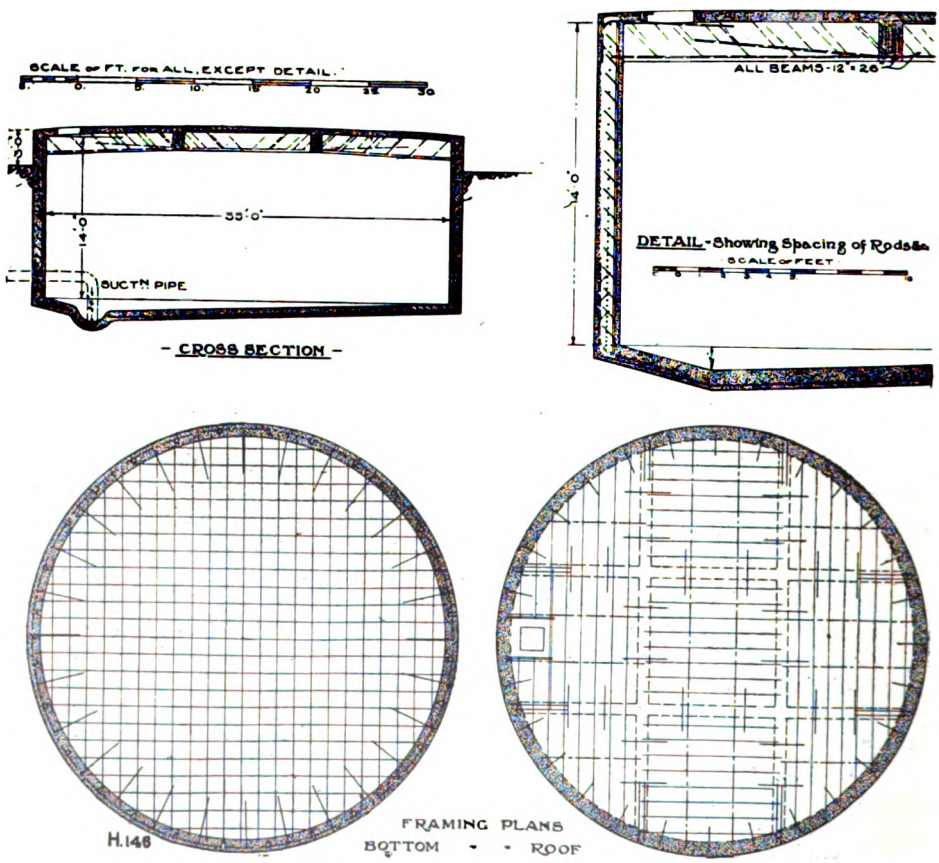

FIG. 3. GALE MANUFACTURING CO.'S REINFORCED CONCRETE RESERVOIR AT ALBION, MICH., U.S.A.

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Service reservoirs in the United States are usually constructed circular in plan; reinforced concrete therefore lends itself admirably for this purpose.

I will first describe a reservoir of this type constructed in 1906 at Bloomington, Ill., U.S.A.

OPEN SERVICE RESERVOIR AT BLOOMINGTON, U.S.A.

This reservoir is constructed throughout of reinforced concrete; it is circular in plan, being 300 ft. in dia., and has a capacity of 10 million gallons. It is uncovered, is 25 ft. deep in the centre of reservoir, the bottom being formed in the shape of a segment of a sphere. The wall is 15 ft. high average, and of the section illustrated in *Fig.* 1, it is 3 ft. thick at its base, and 1 ft. at the top. It has a vertical back and battered face. Owing to the reservoir being built on what was formerly an old sand and gravel pit, there being no other available site, the wall has a concrete foundation 10 ft. in width and 1 ft. 3 in. in depth, with a toe 4 ft. in depth on the inner side. The reinforcement of this wall consists of ¾-in. Johnson bars spaced 15 in., 12 in., and 8 in. centres. The footings are reinforced by ¾ in. bars, spaced 9 in. centres. Some of the bars are extended and turn into the toe of the wall.

Floor.—This is 6 in. in thickness, it slopes towards the centre of the reservoir, and is formed of reinforced concrete, the reinforcement consisting of ¼-in. round rods spaced 6 in. apart in both directions.

The concrete used for the walls and floor was of the following proportions:—1 cement, 3 broken stone (capable of passing through a 2-in. ring), and 4 of fine gravel, containing about 50 per cent. of sand. The concrete was mixed by means of a Foote portable mixer. The concrete on the face of the wall consisted of 1 part cement to 4 parts of fine gravel. The wall was commenced at a certain point, and continued in opposite directions. Before each day's concreting was proceeded with, the previous day's work was washed over with grout of neat cement.

Excavation.—The excavation was carried out by means of a scoop-bucket excavator and completed by hand.

Grouting Face of Wall.—The inner and outer faces of the wall received a coat of cement wash (1 to 1), the inner face also receiving a coat of Star Stettin Portland cement and sand (1 to 1).

Tests.—The work was subjected to some severe tests. Almost immediately the forms were removed the space between the back of the wall and the bank (representing in some parts 10 ft. in depth) was filled with water. This was allowed to remain for 10 days, when the excavator dumped earth into this water. No signs of leakage occurred on the face of the wall, except that at one or two places dampness appeared, and in one place a slight leakage of one or two drops per minute was visible, which was remedied.

Cost.—The reservoir was designed by Mr. D. H. Maury, of Peoria, for the Crescent Stone Co., of Peorin, Ill., U.S.A., who carried out the work, the total cost being $34,000. The reservoir was completed in about 14 weeks, and *Fig.* 7 shows it in its finished state.

PROVIN MOUNTAIN RESERVOIR, SPRINGFIELD WATERWORKS, U.S.A.

This is a very important piece of engineering work, and is now being carried out by the Baker Construction Company, to whom the contract was let on June 18th, 1908. The work is practically completed, and our illustrations show its construction.

This distributing reservoir is being erected in connection with the new water supply (Little River Project), of the City of Springfield, U.S.A. It is situated on Provin Mountain, which is near the city, the top water-level in the reservoir being about 405 ft. above sea level. The reservoir is constructed chiefly of reinforced and plain concrete, and the portion of the works now being installed has a capacity of 16,000,000 gallons. The size of the reservoir is 320 ft. × 288 ft., and the maximum depth of water allowed for is 26·35 ft. The foundation consists of rock and earth, approximately half of each. There is a 38-in. steel pipe rising main coming into the reservoir, and a 42-in. out-go pipe proceeding from it. The particulars as to the construction of this reservoir are as follows:—

Walls.—These are of reinforced concrete backed up by undisturbed rock, and by rock fill (see *Fig.* 2). They are vertical on the inside face, the back of the wall having a batter of 1 in 24. The wall has a minimum thickness of 18 in. at its base, and

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averages at its base about 2 ft. thick. The reinforcement consists of ¾-in. steel rods spaced horizontally at 12-in. centres, with three ¾-in. steel rods running horizontally in some parts of the wall, and in other parts of 1-in. steel rods spaced horizontally at 10-in. centres, with four ¾-in. horizontal steel rods. In other parts the 1-in. rods are spaced at 14-in. centres, and the ¾-in. rods at 2-ft. centres. All rods are twisted, and are specified to be capable of withstanding a tensile stress of 55,000 to 65,000 lb. per sq. in., and an elongation of at least 25 per cent. It was also a condition that they should be twisted cold. The vertical rods not only reach to the top of the walls, but project into the vaulting at least 6 in. The horizontal rods are in lengths of not less than 30 ft., and the ends are hooked to the adjoining rod. All rods were specified to be bent around corners of walls, and no rod was allowed to end at a distance of less than 5 ft. from any corner. The concrete used was in the following proportions:

One American barrel of Portland cement, weighing 380 lb. net; 11 cu. ft. of sand, measured loosely; 19 cu. ft. of ballast, measured loosely. The ballast consisted of crushed rock, broken to such sizes that it would pass through a 2½-in. ring, all particles less than ¼ in. in size being screened out. No plumbs were allowed to be embedded in walls where the latter were not more than 18 in. in thickness, and then they had not to exceed in size one-fourth of the thickness of such walls.

All concrete in walls was deposited in 6-in. layers, and well tamped. Where new work joined old the latter was well cleaned down and well covered with cement grout before fresh concrete was added. All finished surfaces were kept continuously wet. The concrete for the piers, floor, and roof was of the same proportions as used for the walls.

The division wall contains a conduit, and is connected to the floor and roof by steel rods as shown in *Fig.* 2.

Floor.—This varies in thickness from 4 to 10 in., and consists of plain concrete mixed in the proportions previously named. It is flat where on rock foundation, and where otherwise consists of inverted groined arches.

Piers.—These are 2 ft. × 2 ft., constructed of plain concrete, and are spaced at 16-ft. centres.

Roof.—This is of the groined arch type, which is so common in American practice. It is constructed of reinforced concrete, the reinforcement consisting of ¾-in. steel rods spaced at 2-ft. centres. The arches have a rise of 2 ft. 9 in. above springing line, and are 6 in. in thickness at the centre. About 2 ft. of earth filling is placed above the roof. In constructing the roof each square between the piers was constructed monolithic. A depression is made in the concrete roofing over the piers, which is the usual American practice, and is generally estimated to effect a saving of 15 to 25 per cent. on the cost of the roof.

Estimated Cost.—The consulting engineer for this important work was Mr. Allen Hazen, M.Am.Soc.C.E., of New York, whose estimate for the whole of the Little River project was $2,161,000. The contract price for this reservoir was $137,855, but this amount did not include gates, pipes, castings, and other fittings furnished by the city authority, the cost of which Mr. Allen Hazen puts at $10,000; nor did it include engineers' fees and the land, the total cost, including all these items, being about $170,000, which works out at about 0·69 penny per 1,000 gallons of water stored.

REINFORCED CONCRETE RESERVOIR FOR THE GALE MANUFACTURING CO., ALBION, MICH., U.S.A.

This reservoir, shown in *Fig.* 3, was designed by the Trussed Concrete Steel Co., of Detroit, Mich., and was constructed in 1907. It is circular in plan, being 35 ft. in diameter. The walls are 14 ft. in height, 12 in. in thickness, and are reinforced on the Kahn system by means of vertical bars and horizontal and inclined steel rods, the former being ½ in. × 1½ in. spaced at 4-ft. centres, the latter being ½ in; the inclined bars are spaced 12 in. apart. Anchor bars 8 ft. in length and ½ in. × 1½ in. in section, are inserted at 4-ft. centres. The floor is also of reinforced concrete, and is 10 in. in thickness; it has a fall towards a channel, which leads to the outlet. It is reinforced by the insertion into the concrete of ½-in. round rods spaced at 18-in. centre, and running in the opposite direction.

The roof is 6 in. in thickness, formed of reinforced concrete, and is supported by R.C. beams 12 in. × 26 in. The former is reinforced by ½-in. × 1½-in. bars spaced at

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16-in. centres, the latter by $1\frac{1}{4}$-in. × $3\frac{3}{4}$-in. bars 34 ft. long, and $1\frac{1}{4}$-in. × $3\frac{3}{4}$-in. bars 28 ft. long, also by inclined and horizontal bars. Three-fourths of this reservoir is below ground level. A manhole for inspection purposes is formed in the roof. The reservoir has a capacity of 100,000 gallons.

FORT RILEY RESERVOIR, KANSAS.

Fig. 4 illustrates a reinforced concrete reservoir recently constructed at Fort Riley, Kansas. Its capacity is 2,000,000 gallons, and it is 100 ft. in width by 200 ft. in length, the ends in plan being a half circle. The walls are supported by buttresses, which are 18 in. in thickness, and spaced at 12-ft. 6-in. centres.

The reinforcement is on the Kahn system, that in the wall consisting of $\frac{3}{4}$-in. × 2-in. bars spaced at 7-in. and 12-in. centres, and $\frac{1}{2}$-in. × $1\frac{1}{2}$-in. bars spaced at 12-in. centres, and of $1\frac{1}{4}$-in. × $3\frac{3}{4}$-in. bars. The thickness of the wall is 10 in., and it is 15 ft. in height. The buttresses are reinforced by $\frac{3}{4}$-in. × 2-in. bars spaced at 18 and 12-in. centres. The foundation for the buttresses is 10 in. in thickness, and the former is 14 ft. wide. It is an open reservoir, and the floor is 8 in. in thickness, and is reinforced by $\frac{1}{2}$-in. round rods spaced at 4-ft. centres.

The work was designed by the Trussed Concrete Steel Co., of Detroit, Mich.

NAVAL ACADEMY REINFORCED CONCRETE RESERVOIR, ANNAPOLIS, MO.

This was constructed in 1906 from the designs of the Trussed Concrete Steel Co. The reinforcement is again on the Kahn system. The reservoir, which is rectangular (see *Fig.* 5), is 201 ft. × 100 ft. in area, and consists of four compartments, each being 50 ft. × 100 ft. The walls are 12 in. thick, and are reinforced by the insertion into the concrete of $\frac{1}{2}$-in. round bars running horizontally, and $\frac{3}{4}$-in. × 2-in. vertical bars, the latter being spaced at 2-ft. centres. In the partition walls the $\frac{3}{4}$-in. × 2-in. bars are spaced 1 ft. apart. The height of the walls above floor level is 16 ft. 2 in. The piers are 12 in. × 12 in., reinforced by four $\frac{3}{4}$-in. × 2-in. bars, and rest upon a plain concrete foundation 3 ft. × 3 ft. × 1 ft. 6 in. The piers are 16 ft. 4 in. apart. The roof is 6 in. in thickness, and is reinforced by $\frac{1}{2}$-in. × $1\frac{1}{2}$-in. bars spaced at 10-in. centres, and is supported by a beam 20 in. × 12 in. in section, which is reinforced by 1-in. × 3-in. and $\frac{3}{4}$-in. × 2-in. bars. An inspection manhole is provided for each compartment.

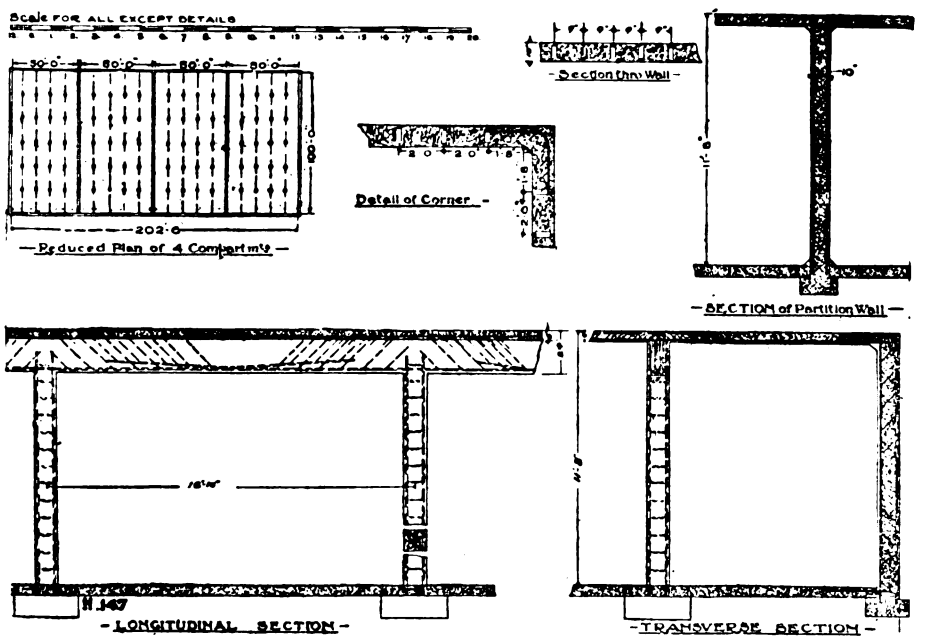

FIG. 5. REINFORCED CONCRETE RESERVOIR AT THE NAVAL ACADEMY, ANNAPOLIS MO.

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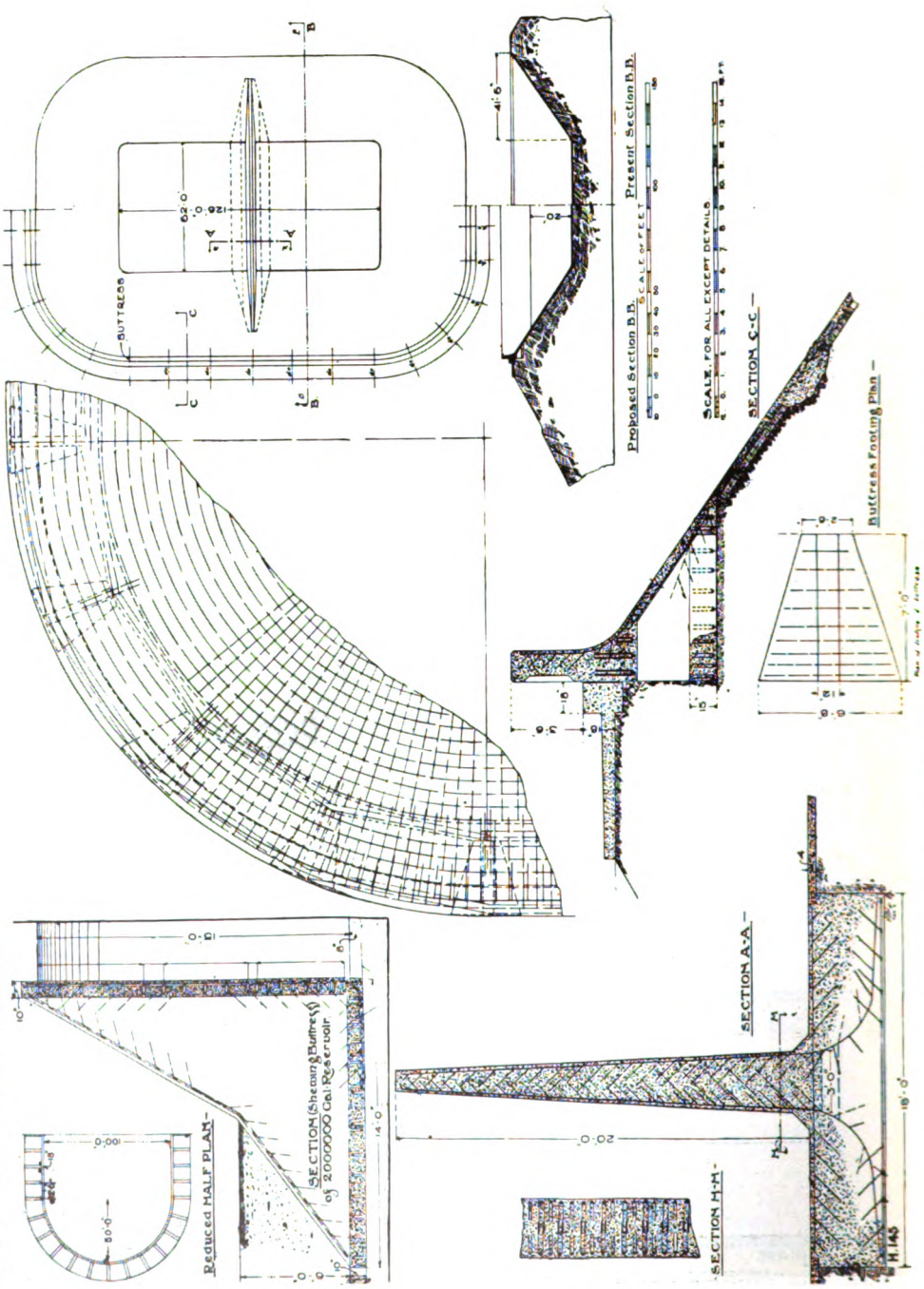

FIG. 4. RESERVOIR AT FORT RILEY, KANSAS.

FIG. 6. THE FORT WAYNE REINFORCED CONCRETE RESERVOIR, INDIANA, U.S.A.

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RESERVOIR AT FORT WAYNE, INDIANA.

Constructed by the Moore Mansfield Construction Co., of Indianapolis, Ind., it is 144 ft. × 206 ft. in size, the corners being rounded; it has sloping sides, and a partition wall across its centre 20 ft. in height. Buttresses 12 in. thick and reinforced with Kahn bars 1 in. × 3 in. and $\frac{3}{4}$ in. × 2 in. are spaced every 20 ft. apart, the footings for these buttresses being 15 in. in thickness and 6 ft. 8 in. in width at the outer end, to 2 ft. 6 in. in width at the inner end. The buttresses extend 7 ft. The floor consists of reinforced concrete 4 in. in thickness placed upon an old brick floor. The reinforcement consists of $\frac{1}{2}$-in. bars spaced at 18-in. centres both ways, and where each buttress occurs $\frac{3}{4}$-in. × 2-in. bars are inserted.

The retaining wall is 5 ft. in height, 3 ft. thick at base, and 1 ft. 6 in. at the top, and is reinforced by $\frac{1}{2}$-in. bars spaced 12-in. centres, $\frac{3}{4}$-in. × 2-in. bars spaced 18-in. centres, and $1\frac{3}{4}$-in. × $2\frac{3}{4}$-in. bars; all bars are on the Kahn system.

The partition wall is 20 ft. in height, 3 ft. in thickness at its base, and 1 ft. at the top, and is reinforced by $1\frac{3}{4}$-in. × $2\frac{3}{4}$-in. and $\frac{3}{4}$-in. × 2-in. bars spaced 12-in. centres. The reservoir is an open one, and is illustrated in *Fig.* 6.

The Finishing of Exposed Concrete Surfaces of Reservoirs in America.—The author would mention that the practice so common among British engineers of rendering the face of the walls, floor, and roof of reservoirs with cement rendering is looked upon by American engineers with great disfavour. They consider that it is practically impossible for cement mortar in thin layers to adhere for any length of time to a concrete surface, and the author's experience leads him to agree with that view.

The practice in the States is, therefore, after the forms are removed, to first point up with mortar of 1 cement to 2 of sand any small cavities which may be visible, and to apply cement grout (1 of cement to 2 of sand) with a brush to the whole concrete surface. Any projections in the concrete due to the joints in the forms are rubbed down before the wash is applied. The author, while in favour of this method, prefers to point up with 1 to 1, or even neat, mortar, and to brush the surface over with neat cement grout.

CONCLUSION.

The author in this article has endeavoured to describe the design and methods of construction of reinforced concrete reservoirs in the United States; as far as he has been able he has also given the cost of the works described, and he would conclude by saying that reinforced concrete for works of this class is considered by our friends across the Atlantic to be an ideal material, and is undoubtedly the material which in the near future will, in that country, be generally adopted in reservoir construction.

The author would express his indebtedness to the City Engineer of Chicago; to Mr. Dabney H. Maury, of Peoria; to The Expanded Metal and Corrugated Bar Co., of Detroit, and to other gentlemen in America who have kindly supplied him with the information given in this article. He would especially acknowledge his indebtedness to Mr. Allen Hazen, M.Am.Soc.C.E., of New York, for the valuable information received relating to the Provin Mountain Reservoir.

Fig. 7. Finished Reservoir at Bloomington, Ill., U.S.A.

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THE USE OF CONCRETE FOR MINE SUPPORTS

By PROF. W. R. CRANE.

We have from time to time presented articles and notes on the importance of using concrete in mines. It now affords us great pleasure in presenting the excellent paper read by Prof. W. R. Crane before the Institution of Mining Engineers at their general meeting, held in May, in which he so ably summarised the present position. We are indebted to the Institution for permission to present this paper.—ED.

Introduction.—Up to comparatively recent times timber has been the principal means of support for underground workings; but, owing to the rapid growth of the mining industry, the available supply of suitable timber has become exhausted to such an extent that its use as an economical material for support is rapidly passing. Further, the falling off in the use of timber has been augmented by the application of concrete, which is now recognised as a reliable and satisfactory substitute for timber. The discovery of materials suitable for making cements, and improvements in the methods for their economical manufacture, are largely responsible for their extended use.

Another important factor favouring concrete is its great strength as compared with timber, which is especially marked in certain applications such as shaft-lining and similar work. Concrete, and especially reinforced concrete, is now extensively employed in mining shafts, mine galleries, tunnels, gangways, in the support of rooms and stations, in building dams and stoppings underground, and, in fact, in all mining work both within and without the mine.

In the search for suitable materials to be employed as substitutes for timber, when it was realised that its use must soon be largely discontinued, stone, brick, iron, and steel were tried in turn, and with varying degrees of success; but it may be said that they have not met with much favour in American mining practice, primarily because of the high cost of transport and the perviousness of the resulting constructions. They are, however, still used, and quite extensively in certain localities, as linings for tunnels, gangways, and stations; while structural steel is now recognised as a standard form of support in the anthracite mines of Pennsylvania and neighbouring States, special shapes and connexions being made for such use.

Advantages of Concrete.—Concrete enjoys the advantage over stone and brick in that it can be more readily placed; as fewer skilled labourers are required, the first cost usually is considerably less, but much more time is necessary to place concrete, even as much as three times that required for timber, thus increasing the cost of construction. Concrete, when once properly placed, is practically impervious and indestructible, requiring but few repairs and no delays, and avoiding the consequent loss of output and expense of maintenance. Moreover, concrete is especially well suited for various applications in mining operations, owing to its adaptability and ease of placing.

Composition and Properties of Concrete.—As the material used in the support of underground working is subjected to excessive pressures and severe conditions, its composition must be such as to ensure the best results. While it is not in the province of a paper of the character of this one to describe in detail methods of manufacture of cements or even the making of concrete, yet a few words as to the character of the ingredients, the proportions employed for various purposes, the strength of concrete, and the relative costs may be given to advantage in this connexion.

Rules to follow.—The only safe rule to follow with regard to the character of the cement to be used in concrete is to get the best obtainable; the cause of failure will

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then be more readily traceable. From extensive experiments, however, carried on in the United States, it seems very probable that the character of a good cement can be materially improved by re-grinding, an operation that can be readily accomplished by the manufacturer at the mill or by the contractor at the mine plant.

The effect upon cements of re-grinding is twofold, namely, decrease in the time required for both initial and final set, and greater strength at the end of shorter periods of time. In certain kinds of work, such as are frequently encountered in mining, these may be weighty considerations, and may even be the determining factors, in the choice between concrete and other materials, the time element entering very largely into such operations as shaft-lining under difficult conditions. However, the fact should not be overlooked that the ultimate strength of coarse cements may be the same or relatively higher at the end of longer periods of time; but the advantage of quickly taking up the load may more than counterbalance a slight reduction in ultimate strength.

Table I. gives a summary of tensile tests on re-ground cements, the first column showing the character of the cement, that is, the time during which it has been subjected to re-grinding.

TABLE I.

SUMMARY OF TENSILE TESTS WITH RE-GROUND CEMENTS.

Sample	At the end of			Mixture of 1 Part of Cement to 3 of Sand at the end of	
	24 Hours	7 Days	28 Days	7 Days	28 Days
	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
Market	135·9	555·3	657·8	167·9	242·7
2 hours	327·9	532·3	619·0	223·3	291·4
5 hours	348·8	568·3	631·3	243·0	350·5
9 hours	291·6	532·9	630·9	267·7	344·4
14 hours	365·0	596·7	598·8	283·1	380·6

Proportioning Cement.—The usual method of procedure in proportioning cement mixtures is to measure the ingredients, thus a 1 : 2 : 4 concrete is composed of cement, 1 volume; sand, 2 volumes; and aggregate, 4 volumes. In order that like results may be obtained in different work and at various times, it is necessary that definite measuring units be employed, that the measuring boxes be carefully and accurately filled, and that there should be at least two boxes to a batch of concrete. Proportions calling for fractional units should be avoided as far as possible. While too much attention to details is not desirable, a certain amount is necessary as preventing carelessness.

Table II. gives the proportion of cement, sand, and aggregate usually employed in mixing concretes for various mining purposes.

TABLE II.

CONSTITUTION OF CONCRETES FOR MINING PURPOSES.

Class of Work	Ratio of Volume of			Average Volume of a Batch in Place, using 1 Barrel of Cement (3·8 cu. ft.
	Cement	Sand	Stone	
				Cu. ft.
Walls	1	1	2	9·7
Retaining-walls	1	1½	3	13·0
	1	2	4	16·5
Shaft-lining ..	1	2	5	18·0
Foundations ..	1	2½	5	20·0
Dams	1	3	6	24·0

Sand.—The character of the sand and aggregate used is also of great importance if the best grade of concrete is to be secured. In mining work the sand problem is often a serious one, and the quality of the concrete suffers accordingly. It is only through careful testing that the effect of the grade of the sand is brought out. The prime requisite is that the sand shall be clean and sharp. While clay, dried and added to the sand as a powder, may have no deterrent effect, yet if, as in nature, it occurs as a slimy coating upon the grains of sand, the result is that the concrete made from it loses both in speed of setting and in ultimate strength. Further, natural sand when properly graded gives a higher tensile strength than crushed stone. This fact is shown to good advantage in the following table:—

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Character of Sand.	Tensile Test: Portland, 2 to 1, 7 days set.
Crushed quartz	266
Good grade natural sand	351
Fine granite screenings	423
Bank sand	273
"	251
"	194
"	111

As noted above, the selected natural sand is excelled only by fine stone dust, while the bank sands show various values, due largely to the presence of dirt and clay.

Aggregates.—Similarly with aggregates, they should be clean, and should consist of gravel, broken stone, or similar high-grade materials. For certain kinds of work gravel is much to be preferred, especially in reinforced concrete constructions, as it can readily be worked into difficult positions. Broken stone should be free from both dirt and dust, unless in the latter case provision is made for it in the proportion of sand added. The aggregate should not exceed ¾ in. in size for reinforced concrete work. Other aggregates of various sizes and materials may be employed in different kinds of work. For instance, it is by no means an uncommon occurrence to use boiler-sinter, slags, tailings, etc., in mixing concrete, especially in mining operations. Other things being equal, the strength of concrete is proportional to the cement content, although the method of mixing has an important bearing upon its strength; machine work gives better results because it is more thorough than hand-mixing.

Concrete has a relatively low tensile sterngth, and should therefore be so employed as to be under compression. This is quite readily accomplished in the uses to which it is put. However, by the use of reinforcements, concrete may be made to resist both compressive and tensile strains, the reinforcement providing the means of resisting the pull or tension, as well as increasing the cohesion of the mass and thus enhancing the resistance to crushing.

The ultimate compressive strength of stone-concrete in 6-in. cubes, and with various proportions of sand and cement, is given in Table III.

Comparisons.—For the sake of comparison, the crushing strength of various classes of brickwork laid in cement-mortar may be cited:—First-class brick gives a test of 834 lbs. per sq. in., while good common brick also laid in cement-mortar gives 486 lbs. per sq. in.

TABLE III.

ULTIMATE COMPRESSIVE STRENGTH OF 6-IN CUBES OF STONE CONCRETE.

Ratio of Volume of			Compressive Strength after One month's Time
Cement	Sand	Stone	lbs per sq. in.
1	1	2	4,000
1	2	4	2,700
1	2½	5	2,300
1	3	6	2,000
1	5	10	1,400

The cost of any material, if it is to receive extended application, is an important item in constructional work; and, as previously pointed out, while the first cost of concrete is, in the majority of cases, considerably less than timber, brick, or stone, yet, owing to the time required in placing, the ultimate first cost may exceed that of timber. From actual experience it has been shown that concrete exceeds timber in first cost from 25 to 45 per cent., the variation depending very largely upon the shape of the construction. If, however, the cost be calculated on the period of service, then concrete has a decided advantage over other materials; the absence or slight cost of maintenance and uninterrupted operations that would otherwise occur are no mean considerations

For purposes of comparison the following data showing costs of timber, brick, and concrete are given:—Yellow-pine lumber, 12 by 12 in. by 16 ft. in size, delivered at points reached by the 23-cent (11½d.) freight rate, sold in the United States during 1907 and 1908 for £5 16s. and £5 3s. 8d. ($28·25 and $25·25) per thousand; while in 1895, 1900, and 1904, such lumber sold for £3 6s. 9d., £3 19s., and £4 6s. 3d. ($16·25, $19·25, and $21·00 respectively). Other lumber, much better suited to mining work, and correspondingly more difficult to get, sells at a proportionately higher price.

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The cost of placing timber will vary largely with the character of the construction, and whether on the surface or underground, but will make the timber cost from 1s. to 1s. 7½d. (25 to 40 cents) per cu. ft., averaging very close to 1s. 5d. (35 cents).

The average prices of common brick, vitrified brick for paving purposes, and front brick throughout the United States in 1906 were £1 5s. 1d., £2 2s. 11d., and £2 12s. 1d. ($6·11, $10·45, and $12·79) per thousand. The cost of first-class brick in cement-mortar is about 1s. 9½d. (44 cents) per cu. ft., 1,000 bricks equalling 40 cu. ft. when laid.

Costs.—While the cost of concrete may be given per unit, as per cu. ft., the figures are of little value unless the costs are given. The following costs of a variety of concrete work per cu. ft. are based upon cement costing 7s. 2d. ($1·75) net per barrel delivered; sand, about 5s. ($1·20) per cu. yd. delivered; broken stone, 7s. 9½d. ($1·90) per cu. ft. delivered; gravel, 4s. 9d. ($1·15) per cu. yd. delivered; labour, 6s. 8d. ($1·62) per cu. yd.; and hand-mixing, 6s. 2d. ($1·50) per cu. yd. in place. The concrete weighs on an average 140 lbs. per cu. ft. To supplement the above the cost of cement per cu. yd. of concrete is given in Table V.

TABLE IV.

COSTS OF VARIOUS KINDS OF CONCRETE WORK.

Class of Work	Cost per cu. ft. of Concrete in Place				
	Broken Stone			Clean Gravel	
	s. d.		Dollars	s. d.	Dollars
Walls	1 3·47		0·314	1 1·50	0·274
Retaining Walls	1 1·95		0·283	0 11·68	0·237
Foundations ..	1 1·01		0·264	0 10·55	0·214
	1 0·12		0·246	0 9·61	0·195
Dams	0 11·33		0·230	0 8·82	0·179
Mass concrete ..	0 10·35		0·210	0 7·88	0·160
	0 9·86		0·200	0 7·34	0·149
Average costs	1 0·29		0·249	0 9·91	0·201

The relative first costs of the three different kinds of materials given are then in increasing order: concrete, 10½d. (21 cents); lumber, 1s. 7½d. (35 cents); and brick, 1s. 9½d. (44 cents) per cu. ft.

TABLE V.

COST OF CEMENT PER CUBIC YARD OF CONCRETE.

Proportions of			Barrels of Cement required	Cost of Cement per cu. yd., Cement costing 6s. 2d. (1·50 dols.) per Barrel net.	
Cement	Sand	Gravel			
				s. d.	Dollars
1	1½	3	1·90	10 2½	2·85
1	2	4	2·48	9 1½	2·22
1	2½	4	1·38	8 6	2·07
1	3	5	1·14	7 0	1·71
1	3	6	1·02	6 6	1·53

Reinforcing Members.—In reinforced concrete, the reinforcing members may be plain, corrugated, serrated, or crimped. While the plain forms are in common use, those with a mechanical bond are preferable. Plain iron rods crimped to a certain extent are frequently used, as are expanded metal and wire screening. However, for certain purposes, old wire rope and steel rails have no equal as reinforcing elements.

It is important that the reinforcement should be definitely and systematically placed, and should not be left to the judgment of the contractor or labourer. The plans should show how and where the reinforcement is to be placed, and sufficient inspection should be given to the work to ensure that the plans are followed; after the metal is covered by the concrete, inspection serves no useful purpose.

The concrete for reinforced work should not be dry, but rather a "wet mix"; while too much water is not desirable it is to be preferred to too little. When placing the concrete about the reinforcement sufficient jarring or movement of the members should be resorted to, to ensure the concrete filling in well, otherwise weakness will result.

Bonding.—Dirt, oil, and grease should not be tolerated, and all junctions or bondings of old with fresh concrete should receive special and careful attention; for even a coating of finely comminuted material, as dust, may constitute a line of weakness and prevent a continuous building up and attachment of crystals between the two portions. The bond is in any case a source of weakness, while careless or improper cleaning of surfaces previous to placing fresh concrete may result in no bond at all. Roughening of the old surface and the placing of a layer of neat cement serve a

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useful purpose in ensuring a good bond between courses of concrete placed at different periods.

APPLICATION OF CONCRETE TO MINING OPERATIONS.

Illustrations of the application of concrete and reinforced concrete to mining operations are given, and are drawn principally from American practice.

Shaft-lining.—Stone, brick, and concrete are used as lining materials for circular and elliptical shafts, while timber both round and sawn cannot be employed to advan-

FIG. 1.—SECTION OF CONCRETE SHAFT LINING AT BRIDGEPORT COLLIERIES, PENNSYLVANIA.

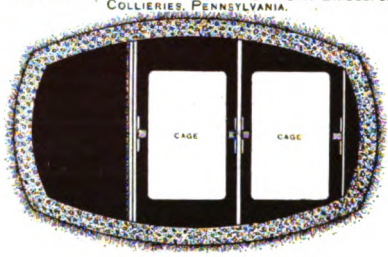


FIG. 4.—SECTION SHOWING CONCRETE USED IN PLACE OF TIMBER IN ROADWAYS.

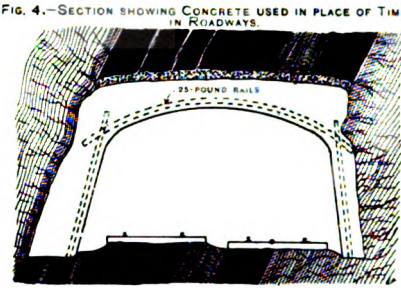


FIG. 2.—SECTION OF CONCRETE SHAFT LINING AT BRIDGEPORT COLLIERIES, PENNSYLVANIA.

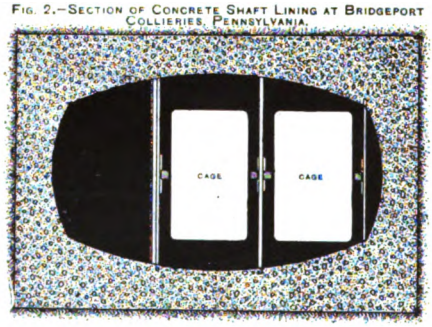


FIG. 5.—PLAN SHOWING CONCRETE USED IN PLACE OF TIMBER IN ROADWAYS.

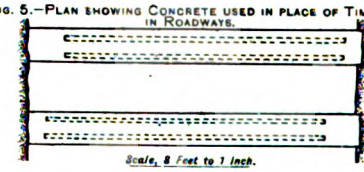


FIG. 6.—PILLAR OF CONCRETE AT INTERSECTION OF THREE ROADWAYS.

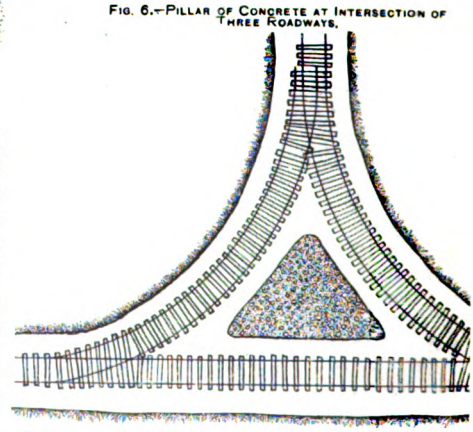
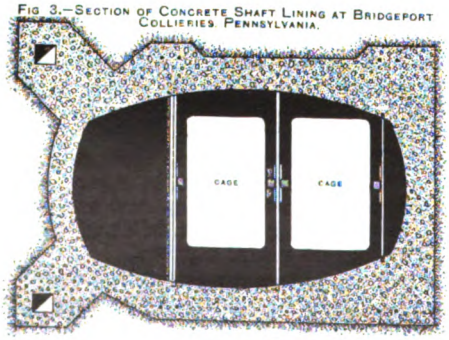


FIG. 3.—SECTION OF CONCRETE SHAFT LINING AT BRIDGEPORT COLLIERIES, PENNSYLVANIA.



FIGS. 1 TO 6. VARIOUS PLANS AND SECTIONS.

tage in other than square or rectangular forms. Concrete has, therefore, the advantage over all other economical and available materials in that it can be applied equally well in shafts of any shape and size. Several rectangular concrete shaft-linings have been successfully constructed in the United States, but practice favours the oval and elliptical forms. Strength and cheapness are the principal reasons for the choice of the circular and elliptical shafts; but these are not economical of space. However, only about half the thickness of lining is necessary when curvilinear forms are employed; therefore the size of the excavation is actually reduced, and the cost of the concrete lining is practically halved.

Elliptical Shafts.—Of the various elliptical shafts sunk in the United States those

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put down by the United States Steel Corporation on their properties at Bridgeport, Pennsylvania, and at Tug River, West Virginia, may be chosen as typical for shafts of this shape.

The Bridgeport shaft-lining measures 23 × 15 ft. in the clear; it was put down as a drop-shaft or sinking-lining through loose surface-material or wash and moderately soft foundations, and was added to until a total depth of 81 ft. was attained. There were three sections to the finished lining, as shown in *Figs.* 1, 2, and 3. *Fig.* 1 is the surface portion, and serves as a foundation for the tipple; *Fig.* 2 is the middle section, and constitutes that portion which was sunk as a drop-shaft; while *Fig.* 3 is the lower section, being largely built up from below. The section (*Fig.* 2) was built upon a heavy timber shoe provided with an angle-iron cutting edge. The dimensions of the shoe corresponded approximately to those of the finished lining, with the exception of the thickness of the forms which were built upon the shoe for the reception of the concrete. As a preliminary operation the shoe was levelled in the initial excavation and 20 or 30 ft. of forms erected. Concrete was then placed and smoothed by running a long-bladed shovel up and down next to the inner form. Periods of ten to twelve days were allowed for the setting of the concrete, after which the outer members of the forms were removed and the operation of settling or sinking the lining begun. This was accomplished and controlled in the usual manner, by removing material evenly from beneath the shoe, which was continued with slight variation until the shoe came to rest upon a hard shale capping the coal. Beginning at a point some 5 ft. lower, an excavation was cut for a foundation ring, and a shell of concrete was built to the drop-shaft above, thus completing the middle section of the lining. The shaft was then sunk through the coal stratum and to a point 10 ft. below it, forming a sump. When completed this last portion of the shaft-lining had a section as shown in *Fig.* 3, but having openings for gangway connections on the longer sides. With the construction of the upper portion, which constitutes the capping of the lining and also serves as a foundation for the tipple, the shaft-lining was complete (*Fig.* 1). As a safeguard against percolating waters while placing the two sections (*Figs.* 1 and 3), strips of canvas were placed against the rock-walls, and concrete filled in between them and the forms. As a further precaution, iron pipes were laid in the concrete, in order that excess of water might be drawn off and thus maintain a low head. Subsequently, when the concrete had set, caps were screwed upon the pipes, checking the flow of water.

The division of the shaft into compartments was accomplished by setting three lines of 8 × 12-in. angle-irons or buntons, holes for their reception being chiselled into the walls, and, when placed, fresh concrete was rammed in around them. It should be said that of the various methods of placing buntons, that mentioned had proved most satisfactory, an attempt at Tug River, West Virginia, to use cast-iron bunton pockets having proved unsatisfactory, owing to excessive leakage around them.

Another instance of the use of a circular concrete drop-shaft in sinking through loose materials (quicksands in this case) is that of the Bangor shaft at Biwabik, on the Mesabi Range, Minnesota. A steel shoe served as the foundation of the superstructure of concrete, upon which two forms were built, an inner one of 14½ ft., and an outer one of 22½ ft., thus leaving a clear annular space of 4 ft. between the two walls of the forms, which is the thickness of the shaft-lining. Owing to the large amount of water encountered, no attempt was made to free the excavation of it during sinking. The sand was removed by dredges of the clam-shell and orange-peel types. To facilitate the movement of the dredges and to control the sinking of the drop-shaft, an inner steel cylinder was employed, being built up of flanged sections and bolted together at the flanges. The cylindrical sections were 6 ft. in diameter and 8 ft. long. Additions were made to the lining as settlement took place by building up forms to a height of 8 ft. for each advance. Successive sections of concrete were then added, which were 4 ft. thick and 8 ft. high, being reinforced by rods of high-carbon steel set into the concrete near the outer form, also staggered somewhat to increase the area of reinforcement. Connections were made between the ends of the rods by roughly forming them into loops, and thus successive lengths were attached as the lining increased in length. A further use of the inner cylinder consisted in employing it as a compressed-air chamber when it was found necessary to work at the bottom of the shaft: the water

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was forced out of the chamber by compressed air, in a manner similar to that employed in caissons, air-locks being established in the tube.

Relining Timber Shafts.—The relining of timbered shafts with reinforced concrete has been successfully accomplished in a number of instances in Pennsylvania, one of the best illustrations of such work being that of the Manville shaft, in the vicinity of Scranton. This shaft is rectangular in section, being formerly lined with 12 x 12-in. timbers, which were reinforced by an inner lining of timbers of the same size, the 6 in. of space left between the two shells being filled with tamped clay. The relining of this shaft was begun at the bottom and proceeded upwards by stages until the surface was reached; it consisted in removing the inner shell of timbers together with the clay packing and placing concrete in its stead; the outer shell of timbers being left as a support of the walls while the concrete was being placed. As soon as 2½ or 3 ft. of lining had been removed, a box form was set in the shaft at that point, and concrete was placed. The outside dimensions of these forms were of the same size as the original shaft compartments. The forms were left in position until the concrete had set, when they were removed and used at a higher point. They were so constructed that a number could be superimposed one upon the other, thus readily building up any height of form desired, close alignment being secured by bevelling the ends of the vertical braces for the sides, which protruded on the upper end, above the sides of the form, the bevelled ends matching and tying the boxes together, but without any positive connection. The space between the outer shell and the built-up form, which was 18 in. wide, determined the thickness of the concrete lining. Two of the compartments, consisting of the hoistway and pumpway, were relined in this manner, while the third compartment or airway was relined within the original lining by using a smaller form and filling in the space between it and the inner shell of timber lining with concrete. The site of the airway was then reduced by 12 in. on all sides, which is the thickness of the concrete lining.

Expanded sheet-metal was used to reinforce the comparatively thin shell of concrete which formed the inner lining of the shaft, the sheets being placed next to the inner and outer forms, and at a distance of 1½ or 2 in. from them. Sheets of expanded metal $\frac{3}{16}$ in. thick and 6 x 8 ft. in size were used, being overlapped at the meeting points. The partitions dividing the shaft into compartments were broken up into buntons by large oval openings being left in them; the old timber buntons were removed previous to the building of the dividings. Tie-rods, $\frac{5}{16}$ in. dia., were used as reinforcement for the partitions, being crimped at intervals of about 16 in. The guides were attached to the partitions by $\frac{7}{8}$-in. bolts, the heads of which with a washer were set into the concrete.

The concrete for this work had a composition of 1 to 2 to 5, the aggregate being broken stone, which was occasionally replaced by fine ash from the boilers, and slate. The concrete was hand-mixed and conveyed to the point where it was to be used by chute. Sufficient water was employed to cause it to fill in well around the reinforcement and stand on the surface of the rammed concrete.

Another shaft was relined at Bellevue and by the same company, the Lackawanna Railroad Company. But while the work was similar, the method of procedure was quite different. This shaft was originally lined with 12 x 12-in. timbers, which were not removed, but a 2-ft. space was excavated at the back of the lining, a temporary support consisting of 2-in. plank being placed against the walls of the excavation. It was found possible to extend the excavation to bed-rock before placing the concrete, when the space between the two shells of timber was filled. Owing to the closeness of the quarters, it was found necessary to lower the concrete in a box or bucket with a capacity of one-third of a cubic yard. It is evident that the conditions of ground were especially favourable, and the amount of water encountered moderate, otherwise the method employed would have proved inadequate.

The Syracuse shaft, also on the Mesabi range, is an excellent example of the use of a variety of methods found necessary to overcome difficult conditions encountered during sinking, the final and successful completion of the work being largely due to the use of reinforced concrete.

Lining of Drifts and Gangways.—As previously pointed out, the comparative shortness of life of timber militates against its use, even where the first cost is not prohibitive. The preservation of mine timber has received considerable attention, especially in the coal-mines of Pennsylvania, and has led to the establishment of a

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number of plants for the treatment of timber. Structural steel is also being used extensively for mine support by certain companies in this State, and the steel mills are regularly manufacturing structural shapes for such purposes. However, it is interesting to note that at least one large company, the Reading, has been experimenting with concrete props, which have proved so successful that it is proposed to build a plant at the North Franklin colliery, where such props will be manufactured and distributed to neighbouring collieries. This movement augurs well for the future use of concrete props in mines.

Gangways, drifts, and stations were probably the first portion of mine workings to invite the attention of the concrete engineer, and while hydraulic cement has long been used in mortars for laying brick and stone walls and linings, yet it was a long time before a venture was made at the use of all-concrete constructions. Brick laid in cement-mortar has at present probably a wider application than concrete; however, its use in preference to concrete is usually for reasons of weight, such as cost and accessibility, rather than for superiority of construction.

The substitution of reinforced concrete for timber in gangways is well illustrated by the practice in the mines of the Philadelphia & Reading Coal & Iron Company, near Shamokin, Pennsylvania. In the majority of places where it is employed, long spans are necessary, owing to double tracks, and arches supported on columns are constructed. These arches have taken the place of timber sets composed of 14 to 16-in. posts and caps, lagged with 4 to 6-in. round timber, and spaced at intervals of 5 ft., centre to centre. In the construction of the concrete arches, the forms were placed close to the timber sets, and were built of 1 x 8-in. boards, with 2 x 6-in. braces. In order to ensure sufficient strength, the arches were at first made 24 in. square, while later ones have been reduced to an 18-in. square section. Further, the earlier forms were reinforced by old 25-lb. rails, being placed side by side and equidistant from the sides in the inner corners. The rails were roughly bent to conform to the shape of the arch, and for ease of handling three lengths of two rails each were used. In the last arches built, old wire rope was used in place of the rails, being woven backwards and forwards through the concrete. Two weeks are allowed for the concrete to set, when the forms are removed, and the arches are complete. All fears as to strength have been dispelled since these arches were built, as no cracks or other signs of weakness have developed in them. The cost is approximately about £5 11s. and £4 10s. 4d. ($27 and $22) respectively, for the 24 and 18-in. sizes (*Figs.* 4 and 5).

Pillars.—Great pillars, usually triangular in shape, are often built at the intersection of roadways where large triangular spaces occur that are much too wide to stand unsupported; and as it is important that no settlement should take place, wooden cribs with or without rock-filling, are unsatisfactory. Concrete is now being successfully applied at such points (*Fig.* 6).

Stations for underground machinery such as pumps, engines, stables, offices, etc., are now, in many of our large mines, being lined or relined with concrete. Two general forms of such constructions are shown in *Figs.* 7 and 8.

Stoppings and Overcasts.—Concrete in coal-mine workings has the advantage over timber and stone in that with little care in surfacing the resistance to air-currents is materially reduced, a circumstance which, together with the considerations of greater strength and durability, is rapidly extending its use. Probably no portion of the airways should be constructed with greater care than the "over-casts," and for that reason concrete is being used in their construction. Concrete over-casts are being employed at widely separated localities in the United States, showing the recognition of their special adaptability to varying conditions. Two instances may be cited of the use of concrete in the construction of over-casts, namely, in the coal-mines at Flat Top, Alabama, and in the mines of the Wyoming coal region of Pennsylvania. In the latter case the Lehigh Valley Coal Company is substituting reinforced concrete for wooden and stone over-casts.

Shapes and Cost.—The shape of the over-casts is usually varied to suit the particular conditions existing at the point where they are located. In form they resemble large concrete troughs mounted upon end-walls; however, the bottom may have to be arched or given a broken slope to accommodate a pitching seam or haulage system, which ways they usually cross. The floor of the over-cast is reinforced with 25-pound T-iron rails, spaced some 2 in. from the lower side of the 12-in. concrete bottom. The walls of the trough-like bridge are extended upward to the state top, with which

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connexion is made. The cost of such an over-cast, including the supporting masonry end-walls, is about £75 ($365); the masonry wall costing 6s. 8d. ($1·63), and the over-cast £2 3s. ($10·50) per cu. yd. The above costs are probably somewhat higher than usual, owing to the removal of considerable rubbish before work could be begun.

Air-stoppings.—Next in importance to over-casts in mine-ventilation are "air-stoppings." The problem of ensuring brattices and stoppings against injury from explosions of gas and coal-dust has been largely solved by the employment of reinforced concrete. A wall of concrete is built across an air-passage at the desired point, being set into the walls, roof, and floor to a sufficient depth to prevent leakage of gas or air, and to give adequate strength. Occasionally an opening is left in the stopping, which is further provided with a wooden or canvas door, being known as a "brattice explosion door." The door is usually placed at such a height, and is of such size, that men can readily pass through, and will permit a large volume of gas or air to pass should an explosion break it down, thus relieving the fan from undue pressure, which otherwise might damage or demolish it. Where air-stoppings

Fig. 7.—Station for Underground Pumps, Engines, Stables, etc., Lined with Concrete.

Figs. 7 & 8. Comparative Sections.

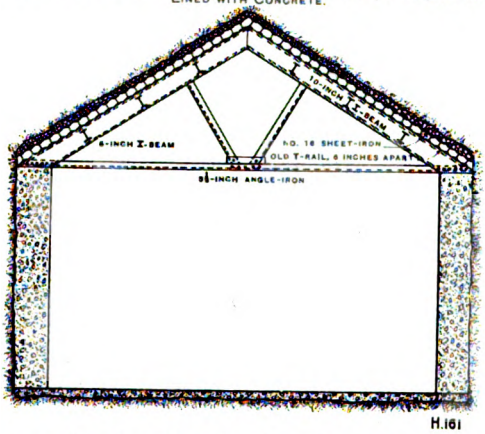
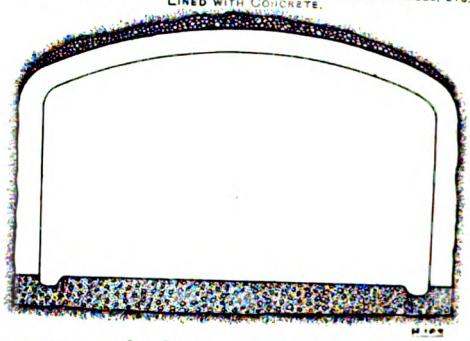


Fig. 8.—Station for Underground Pumps, Engines, Stables, etc., Lined with Concrete.



can be placed in abandoned or little used passages, and where such stoppings are so situated that their effect in checking the force of explosions will not result in damage to the fan, air-tight constructions may be employed. The use of concrete in such work is now common practice, and, as light constructions are most desirable, reinforced concrete is usually employed. A number of concrete air-stoppings have been constructed in the coal-mines at Flat Top, Alabama, in the Birmingham district. A brief description of a stopping in these mines may serve as an illustration of similar work, being simple in construction. To ensure good contact between the walls and the concrete, the walls, roof, and floor, are carefully dressed and recessed to a depth of several inches. Wire-netting of about 2-in. mesh is then stretched across the opening, which, with the recessing, may be made as much as 10 ft. sq., and fastened temporarily by iron pins driven into the walls. Widths of netting exceeding one-half the width of the opening should be chosen, in order that two widths may be used with an overlap in the middle, thus giving double reinforcement where most needed. A form is then erected on either side and the concrete placed, being carefully rammed, especially around the walls. The usual thickness of such stoppings is from 8 to 10 in.

Bulkheads.—It is now common practice in those mines and workings where large quantities of water are liable to be encountered to build bulkheads in the gangways and tunnels as a means of protection to both men and workings. The reinforced concrete bulkheads recently erected in the Ontario adit, which was driven as an extension into the property of the Daly-West mine, at Park City, Utah, are excellent examples. These bulkheads are located in the adit at points 100 ft. or more back from the intersections of passages employed in skirting caved ground. The bulkheads are 12 ft. sq. in the vertical plane normal to the adit, and 9 ft. in length or thickness. The rock-section of the adit measures 5 × 7 ft., and as the bulkheads are 12 ft. sq., the walls

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must be recessed to a depth of 3½ ft. on the sides and 2½ ft. at the top and bottom. The bulkheads are provided with an opening measuring 4 × 5 ft., in the clear, to serve as a doorway for the passage of men, cars, etc. Fitted to this opening is a door constructed of ⅜-in. plates and 10-in. I-beams, securely bolted together, the latter standing vertically, facing the workings. The plates are bolted to the flanges of the I-beams, that portion to which the hinges are attached being of double thickness, made by two plates. Concrete is rammed in between all plates and beams, thus making an extremely strong and impervious construction. Forty 3-in. pipes are set into the concrete, running lengthwise of the bulkhead and extending several inches beyond both faces. These pipes are provided with valves, in order that the pressure upon the bulkhead may be increased or relieved as occasion demands (*Figs.* 9 and 10).

Other Uses of Concrete.—Owing to the rapid wear and decay of timber support for tracks in inclined mine shafts, and owing to the delays and inconveniences experienced in making repairs, the advisability of employing concrete for the support of tracks has been seriously considered, and now that it has been tried and proved eminently successful its rapid extension in such work is practically assured. While transverse stringers or ties can readily be constructed, obviously a long continuous support is preferable; this form being the one usually employed. Such stringers are now in use in the Ahmeek, Mohawk, and other mines in the vicinity of Calumet, Michigan. A section of a concrete stringer, encased in the mould, as may be seen at the Ahmeek mine, is shown in *Figs.* 11 and 12. Preparatory to placing the

FIG. 9.—REINFORCED CONCRETE BULKHEADS IN ONTARIO ADIT, DALY WEST MINE, UTAH.

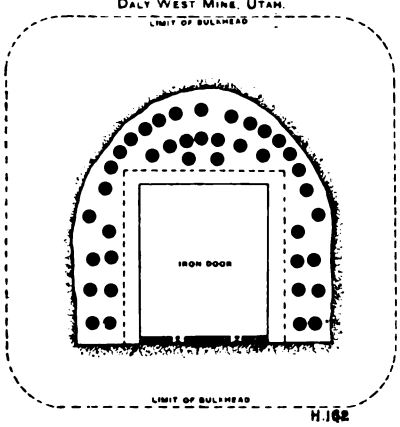
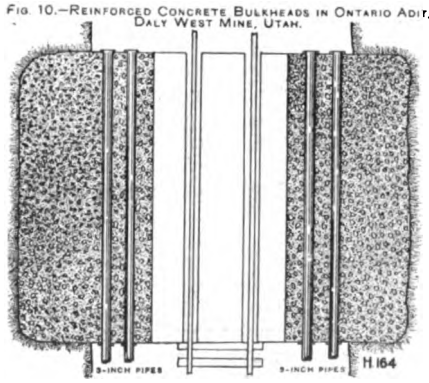


FIG. 10.—REINFORCED CONCRETE BULKHEADS IN ONTARIO ADIT, DALY WEST MINE, UTAH.



FIGS. 9 AND 10. REINFORCED CONCRETE BULKHEADS.

stringers, the floor of the shaft is cleared of loose material, and the mould-boards placed; but, before placing the concrete, the space within the mould is flushed to bed-rock, ensuring a clean face for the concrete. Through the centre of each stringer runs an old wire rope 1⅛ in. dia., which is the only reinforcement found to be necessary. Such stringers have been in use in the copper mines of Lake Superior for six or eight years, being entirely satisfactory.

Retaining Wall Cost.—One of the first applications of concrete in engineering work was the building of foundations for heavy machinery, engines, pumps, compressors, reducing machinery, etc., its use not being confined to the surface only. Retaining walls are now largely built of concrete and reinforced concrete, and are widely employed in the support of fills, as when the site for buildings must be partly excavated and partly filled or built up. Retaining walls should be built in vertical sections or panels, each panel being a day's work; this eliminates horizontal joints. Further, panels should be built alternately, the intermediate spaces being filled in subsequently. With reinforced concrete retaining walls, the base may be made comparatively wide but thin, while the body of the wall, if properly designed, may be fully one-third less in thickness than a similar structure built of unreinforced concrete. The comparative costs of a reinforced and gravity concrete retaining wall 20 ft. high were, in one case,

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£4 18s. 3d. and £8 9s. ($23·94 and $41·17) per linear foot respectively. On the above basis, the gravity wall alone cost 41 per cent. more than the reinforced wall, and was much less stable. The difference in cost between a reinforced concrete wall and a masonry gravity wall would be still greater, while the difference in strength would be still more pronounced.

Concrete for Weak Roofs.—While culm, tailings, and stone have received extensive use in the mines of the United States, in the so-called flushing and filling methods, yet the use of concrete for this purpose has been little more than tried, except in the application of cement to fissured formations; thus by the formation of a natural concrete, as it were, comparatively large areas are rendered solid by cementation. A possible and extremely practicable application of concrete to the support of weak roofs during the extraction of the mineral is employed in Europe, especially in Burgundy, where thick coal-seams are worked in benches. The coal is worked from above downwards, the benches, as excavated, being stowed with waste. Each bench, when the one above it is excavated, is covered with a bed of concrete 8 to 10 in. thick, which also serves as a support for the tracks. The concrete is placed in sections transversely to the working face, good connexion between the successive sections being ensured by leaving a feather-edge on the advancing side. This layer of concrete supports the filling while the bench below is being excavated.

FIG. 12.—SECTION OF CONCRETE STRINGER AT AHMEEK MINE, MOHAWK, MICHIGAN.

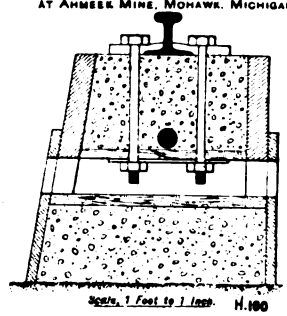
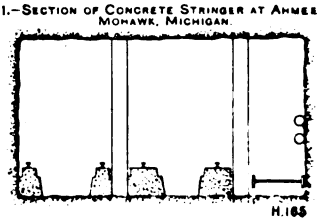


FIG. 11.—SECTION OF CONCRETE STRINGER AT AHMEEK MINE, MOHAWK, MICHIGAN.



FIGS. 11 AND 12. CONCRETE STRINGERS.

Concrete Plates.—Concrete plates have been successfully employed at the Kœnig colliery, in the Saare district, Germany. Blocks 9½ in. thick and of a length equal to the longer dimension of the shaft section, are reinforced by ⅝-in. iron rods spaced 2 to 4 in. apart, and running longitudinally through the plates. They are still further reinforced by 6-in. ribs, two to a plate, and built on the side placed opposite the inside of the shaft. When in place, the corners are strengthened by angle-irons (2 × 2 in.), which, with additional rods set in regular order about the shaft, give ample support for the preliminary operation of lining. Finally, concrete is rammed between the plates and walls, uniting the plates with the rock. The plates then serve the double purpose of a firm and a finished lining, both simplifying and cheapening the operation.

Generally.—The uses of concrete cited in this paper illustrate fairly well the present practice in the United States; however, the various uses to which it is put in and about the mines of this country are manifold, and can hardly be more than mentioned in this connexion. Powder-magazines, both above and below ground, are now very largely built up wholly or in part of concrete; warehouses and the first storey or two of mill buildings are frequently made of reinforced concrete; ore-bins and coal-pockets of a wide range of forms and capacities are now being brought into line with the general trend of practice, and are made of concrete; dams and settling tanks, intercepting ditches, shaft-rings and sumps, etc., are also made of concrete. Having reluctantly tried and found that concrete is good, strong, durable, and reliable, American engineers are wont to go a step further and reduce both the amount and cost. They are, therefore, turning to reinforced concrete, which will undoubtedly work as great a revolution in methods of construction as did the introduction of plain concrete.

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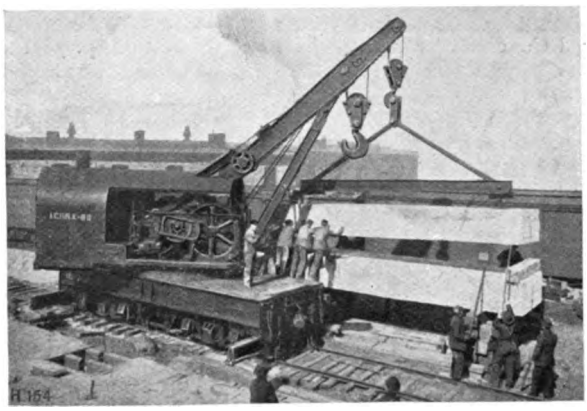
Tests on full-sized Reinforced Concrete Slabs.

Summarised by
Chas. F. MARSH,
M.Inst.C.E.



It is with great pleasure that we are able to present some results of tests with reinforced concrete beams which were undertaken at the University of Illinois. These tests were conducted by Prof. Arthur N. Talbot and formed the subject of Bulletin No. 28 of that University. The summary that we present below has been specially prepared for us by Mr. Charles F. Marsh.—ED.

PROF. A. N. TALBOT, of the University of Illinois, U.S.A., carried out tests in April, 1908, on three slabs 25 ft. long and $6\frac{1}{4}$ ft. wide, and 34 in. deep at the centre of the span. The slabs were constructed at a railway depôt in Chicago by the Illinois Central Railway, for use as a cover for carrying an eight track railway over a street, and the tests were carried out close to this depôt.

Fig. 1 gives the dimensions of the slabs and the methods and sizes of the reinforcement. It will be seen that two methods were utilised for the reinforcement against diagonal tension. The concrete was guaged in the proportions of 1 to 2 to 5, and was mixed in a batch mixer, sufficient water being used to allow of the concrete being deposited with little or no ramming. The reinforcements were carefully placed and held by wires and blocks until the concrete was in place. The sides of the moulds were removed 48 hours after moulding, and the slabs left exposed to the weather for about six months before testing.

Prof. Talbot states that owing to the weather prevailing at the time the conditions were probably less favourable for hardening than is the case in ordinary three-month laboratory tests.

Fig. 2 shows the testing apparatus by which two slabs were tested at the same time, the load being applied by hydraulic jacks of 100 tons nominal capacity. Timber bearing plates of uniform quality were used, and the considerable compression developed in these timbers permitted a good adjustment of the load across the whole width of the slabs. The timbers were bedded in plaster of Paris above and below to overcome any small irregularities in the surfaces of the slabs. Besides measuring the deflections, the longitudinal and vertical deformations were measured with extensometers.

Data of Tests.—Table I. gives the combined deflections of slabs Nos. 70 and 71, and it is stated that it is probable that the individual deflections of the slabs were nearly the same except near the end of the test.

Table II. gives the data and calculated values for slab No. 72. The "stress in steel from deformation" is calculated by multiplying the deformation of the steel determined from the extensometer readings by 30×10^6. The "From bending moment" is calculated by equating the bending moment to $0{\cdot}87Afd$, the approximate value for the resisting moment, as derived by Prof. Talbot from his former experiments ("Reinforced Concrete," by Marsh and Dunn, 3rd edition, p. 400).

Fig. 3 gives the deflections and deformations of slab No. 72 in diagrammatic form.

Figs. 4 and 5 show diagrammatically the vertical deformations of slabs Nos. 71 and 72 respectively, and Table III. gives the miscellaneous calculated stresses, the shearing

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stresses being calculated by the formula $k \max = \dfrac{K}{b\left(h - \frac{u}{3}\right)}$ as put forward in "Reinforced Concrete," Marsh and Dunn, 3rd edition, p. 380.

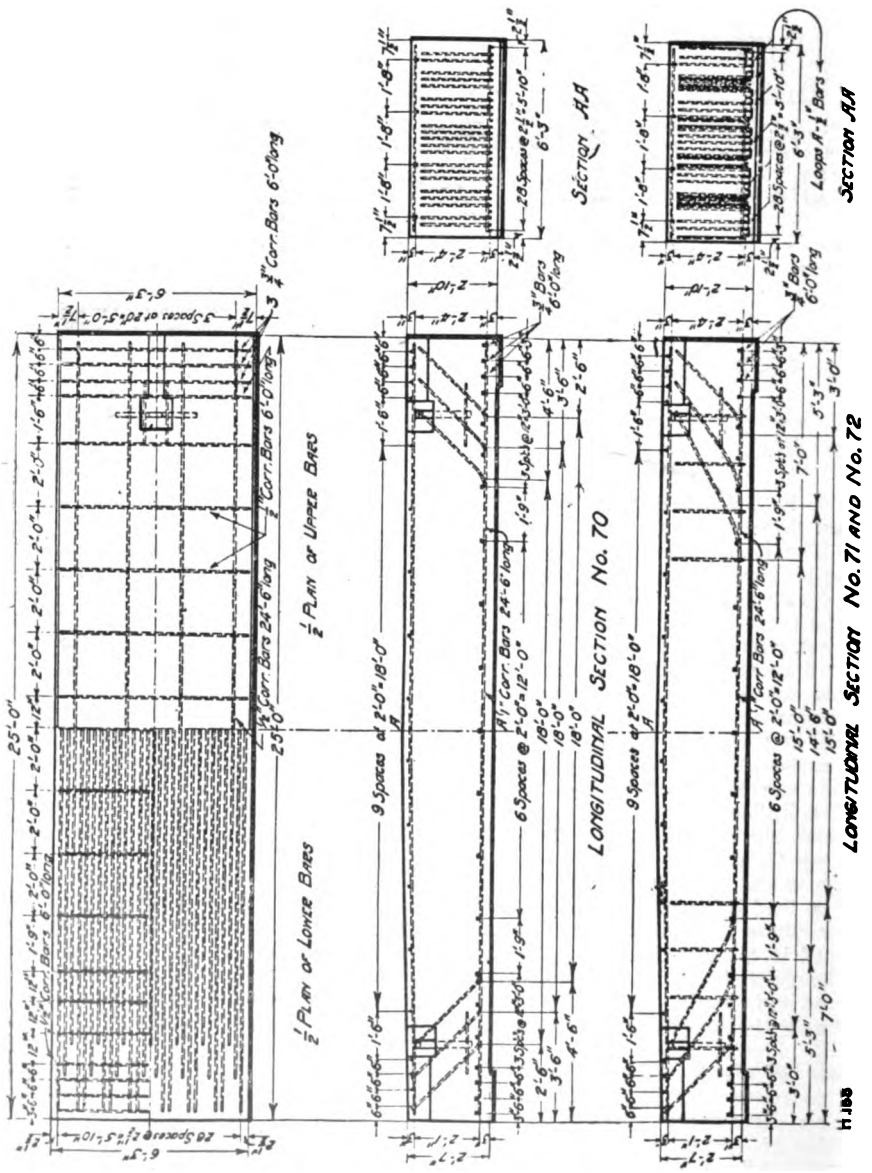

FIG. 1. SLABS UNDER TEST.

Phenomena of Tests.—The usual minute vertical cracks on the tensile side became visible between the load points as the load was applied, and outside the load points at higher loads, becoming more marked and longer as the load was increased.

In slabs Nos. 70 and 71, which did not fail by the stretching of the longitudinal reinforcements, the tensile cracks closed up and were scarcely visible on the removal

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of the load. Slab No. 71 was whitewashed, and the first tension crack became visible at a load of 159,000 lb., and numerous cracks at a load of 189,000 lb., while in the case of slab No. 70, which was not whitewashed, the first tensile crack became visible at a load of 330,000 lb., and numerous cracks at a load of 496,000 lb. Some of the minute cracks extended to within 12 in. of the compressive surface before the longitudinal reinforcements were stressed to their yield points, and even when cracked to this extent the width of the fissure on the tensile side was minute.

Outside the load points diagonal cracks appeared frequently, commencing from the end of a vertical crack already visible and extending diagonally upward and downward at the same time. The diagonal cracks developed with the addition of the load, but the form of this development differed in No. 70, which was without stirrups, from that in No. 72, which was provided with stirrups. In No. 70 one main diagonal crack formed outside each load point, making an angle of about 35° with the horizontal. While a few others became visible, these main cracks enlarged, and the final failure of the slab was along one of them. In No. 72 (whitewashed surfaces) marked diagonal cracks appeared at 447,000 lb., and became numerous and extended at 480,000 lb. Some of these finally extended to within 12 in. of the top face of the slab, but they remained small and fine, and were well distributed over the beam. They lacked the growth and concentration which are apparent in failures by diagonal tension when reinforcing bars are carried straight to the end of the beam or nearly to the end and when stirrups are not used.

TABLE I.

TEST DATA OF NOS. 70 AND 71.

Tested April 15th, 1908.

The applied load includes the weight of the testing appliances, but not the weight of the slab itself. The notes regarding cracks refer to No. 70.

Applied Load	Sum of Centre Deflections of Nos. 70 and 71		Remarks
	E. Side	W. Side	
lb.	ins.	ins.	
25,000	0·00	0·00	This load is used as the weight of testing apparatus and men *plus* the initial tension in the wrought-iron rods.
79,000	0·01	0·01	—
113,000	0·05	0·03	—
140,000	0·07	0·03	—
174,000	0·12	0·08	—
202,000	0·17	0·14	—
230,000	0·19	0·16	—
261,000	0·19	0·21	—
290,000	0·24	0·28	—
333,000	0·36	0·33	First tension crack noted in No. 70.
364,000	0·37	0·40	Small tension crack at north load point.
396,000	0·44	0·46	—
432,000	0·47	0·53	Second tension crack near centre of top slab.
468,000	0·57	0·60	First diagonal crack outside north load.
496,000	0·63	0·69	Numerous small tension cracks.
532,000	0·65	0·77	—
561,000	0·78	0·83	—
593,000	0·85	0·90	First diagonal crack lengthening rapidly and becoming more marked.
626,000	0·98	1·04	Cracking along the steel at south end.
661,000	1·06	1·08	—
693,000	1·11	1·21	In the interval after 488,000 lb. other diagonal cracks appeared near the first one.
734,000	1·24	1·30	First diagonal crack opening wide.
768,000	1·34	1·45	—
801,000	1·60	1·72	Failed suddenly along first diagonal crack, which reached top just inside the load point.

TABLE III.

MISCELLANEOUS CALCULATED STRESSES.

Applied Loads	Calculated Tension in Steel	Calculated Shearing Stress	Remarks
			No. 70.
lb.	lb. per sq. in.	lb. per sq. in.	
333,000	22,800	—	First tension crack noted.
468,000	—	125	First diagonal crack noted.
593,000	—	156	One main diagonal crack extending rapidly.
734,000	—	195	One main diagonal crack opening wide.
801,000	51,700	209	Failure by diagonal tension.
			No. 72.
159,000	12,500	—	First tension crack noted.
447,000	—	120	Marked diagonal cracks noted. Marked increase in vertical extensometer readings.
480,000	—	128	Diagonal cracks numerous and extending.
514,000	—	138	Marked increase in second extensometer readings.
811,000	52,400	—	Tension cracks opening wide.
840,000	54,000	220	Failure by tension in steel.

The calculated stress in steel and the calculated vertical shearing stress include the stress due to weight of slab.

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Manner of Failure.—The manner of failure was quite different in the two beams, Nos. 70 and 72. In the case of No. 70, although it is evident from calculations that the steel of the reinforcing bars had nearly reached the yield point, there was no evidence of this in the appearance and action of the beam at the time of failure. At a load of 593,000 lb. the main diagonal crack outside of one load point was seen to be extending rapidly, and at 734,000 lb. it was opening wide. It was evident for some time that the beam was on the verge of total failure. Finally, it failed suddenly by diagonal tension, so-called shear failure, at an applied load of 801,000 lb., the diagonal crack having suddenly extended to the top of the slab and opened wide. At the same time the horizontal crack which had formed along the reinforcing bar (by the action of the vertical tension) lengthened, and the bar pulled away from the concrete above. The characteristics of this test were the formation of main diagonal cracks at either end, and the final sudden failure of the beam by diagonal tension. In No. 72 the presence of the stirrups and the changed position of the reinforcing bars at the ends were sufficient to resist the diagonal tension developed. Although the diagonal cracks were numerous, and although some of them finally extended to within 12 in. of the top face of the slab, they remained small and fine, and were well distributed.

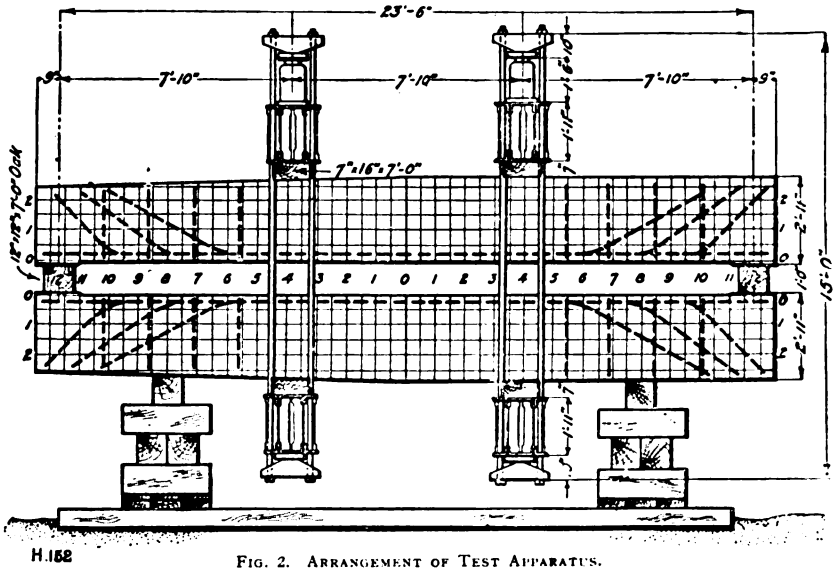

FIG. 2. ARRANGEMENT OF TEST APPARATUS.

They lacked the growth and concentration which are always apparent when the final failure is by diagonal tension. The tension cracks in the middle third of the beam extended upward as the load was increased, and at 811,000 lb. nine of these were visible to within 12 in. of the top of the slab. At this load the tension cracks were opening wide, indicating that the yield point of the reinforcing steel had been passed. Above 800,000 lb. the deflection increased rapidly. The maximum load applied was 840,000 lb., the indicated load then falling off when the deflection was increased. It seems evident that a load of 811,000 lb. would not have held long, and the maximum load applied held but momentarily. The characteristic of the test of No. 72 was slow failure by tension of the steel, without sign of compression failure and without sign of impending failure by diagonal tension. The effectiveness of the stirrups and the bending of the bars at ends were evident in this test.

Position of Neutral Axis.—Prof. Talbot notes that the position of the neutral axis obtained from the extensometer measurements seemed abnormally high, averaging during the later stages about 0·34 of the distance from the compressive surface to the axis of the longitudinal reinforcements. The proportionate depth of the neutral axis for the amount of reinforcement used, based on the ordinary assumptions, would be 0·47 for a ratio of $\frac{Ef}{Ec}=15$. The cause of this appears to have been a slight slipping

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of the extensometer instruments on the compression side between the loads of 220,000 and 320,000 lb. Prof. Talbot gives it as his opinion, based on data and from experience in other tests, that the position of the neutral axis between loads of 400,000 and 750,000 lb. averaged about 0·40 of the effective depth, and points out that such a slip of the extensometers would make the real compressive deformation greater than that given in *Fig.* 3, and the real tensile deformation less.

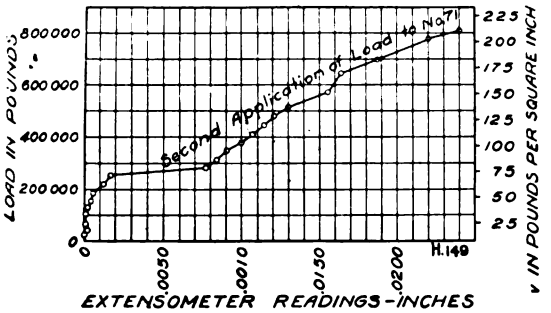

Fig. 4. Vertical Deformation Diagram for No. 71.

Tensile Stress in Reinforcement.—The tension in the main reinforcing bars at the middle of the span length in No. 70, calculated by the usual methods (using the formula 0·87 *Afd*, before referred to), and including the effect of the weight of the beam, was 51,700 lb. per sq. in. at the maximum applied load of 801,000 lb. As the tension cracks in the concrete closed up after the failure of the beam and the release of the load, it would seem that the steel had not been stressed beyond its yield point. In No. 72 the calculated tension in the reinforcing bars, including the effect of the weight of the slab, was 54,000 lb. per sq. in. for the maximum applied load of 840,000 lb. For the applied load of 811,000 lb., where the yield point had evidently been passed, the calculated tension was 52,300 lb. per sq. in. It seems probable that the yield point was reached at the applied load of 780,000 lb. These values approximate closely to the yield point of the steel within the recognised limits of variation.

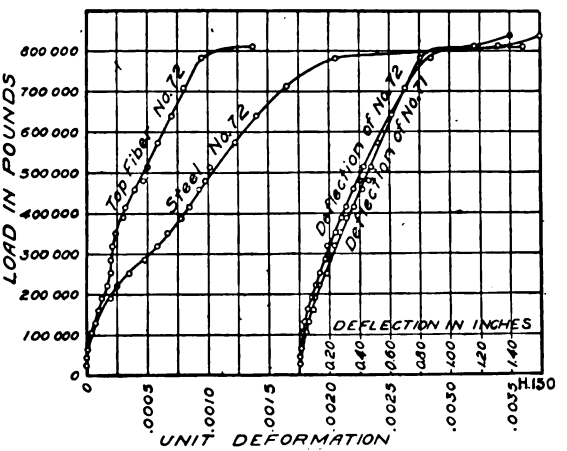

Fig. 3. Load-deformation and Deflection Diagram for No. 72.

Resistance to Diagonal Tension.—Prof. Talbot points out that as the diagonal tensile stress which is developed in the concrete depends upon the horizontal tensile stress existing in the concrete and the effect of stirrups, its amount is indefinite, and the value of the vertical shearing stress may be used as a means of comparison for the resistance to diagonal tension. The vertical shearing stresses were calculated by usual formula as given $\left(h-\frac{u}{3}\right)$, being assumed as $0{\cdot}87h$. Calculated tables for the various loads are given in Table III.

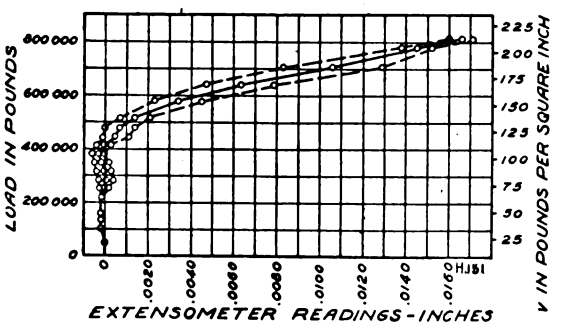

Fig. 5. Vertical Deformation Diagram for No. 72.

For beam No. 70 the value of the vertical shearing stress at the breaking load is 209 lb. per sq. in. This is a high value for a beam without stirrups and having bars bent up abruptly at the end, and shows a good quality of concrete. The value of k max for the applied load of 468,000 lb., where the first diagonal crack was noted, is 125 lb. per

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sq. in.; and for the applied load of 593,000 lb., where the main diagonal crack was seen to lengthen rapidly and become more marked, it is 156 lb. per sq. in.

In No. 72 the value of the vertical shearing stress k max at the maximum load applied is 220 lb. per sq. in. As there was no sign of impending failure, and as the diagonal crack closed up after the failure of the beam, it is seen that the provision against failure by diagonal tension was very satisfactory. By reference to *Fig.* 5 it will be seen that for the lower loads the instruments show a vertical shortening, and that the deformation soon changes to elongation, this change taking place at loads corresponding to loads which gave diagonal cracks in the test of No. 70. The amount of this elongation rapidly increases with the application of further load.

Compressive Stresses in Concrete.—With regard to this, Prof. Talbot states that the compression in the upper fibre, calculated by ordinary methods, runs up to a high figure, as is usual in tests of beams having a considerable amount of reinforcement and adequate provision for web stresses. Assuming the neutral axis to be 0·43 of the depth, to the reinforcing bars, and using the ordinary straight-line formula, the compressive stress in No. 72 at the maximum load was 3,100 lb. per sq. in. Using the parabolic formula, and considering that the compressive deformation is half of the ultimate compressive deformation of the concrete, the calculated stress is 2,870 lb. per sq. in. Even at this high calculated stress there was no sign of compression failure, and none was apparent until after the steel had stretched beyond its yield point. Comparing the deformation developed with that of other tests, it seems probable that the beam would have taken at least one-third more compressive stress before failure in compression at first load would have resulted.

TABLE II.

SLAB No. 72.

Tested April 28th, 1908.

The applied load includes the weight of the testing appliances but not the weight of the slab itself.

Applied Load	Average Deflection	Average Extensometer Readings		Vertical Extensometer Readings		1	2	3	4	5	Remarks
		Top	Bottom	South	North	k of Neutral Axis	Unit Deformation		Stress in Steel † lb. per sq. in.		
							At Steel	At Top Fibre	From Deformation	From Bending Moment	
lb.	in.	in.	in.	in.	in.						
25,000*	0·00	·000	·000	·0000	·0000						The "Average Extensometer Readings" are for a gauge distance of 50 in.
45,000	0·00	·000	·000	·0000	·0000						
67,000	0·01	·001	·001	—·0001	·0000						
103,000	0·02	·004	·004	—·0001	—·0003						
131,000	0·03	·006	·006	—·0001	—·0002						
159,000	0·05	·008	·010	—·0002	—·0003						
						·000	·00000	·00000	—	1,500	Short tension crack just inside south load point
						—	—	—	—	2,700	
189,000	0·10	·011	·016	—·0002	—·0002	·549	·00001	·00001	300	4,100	Numerous tension cracks
						·549	·00004	·00005	1,200	6,300	
220,000	0·11	·015	·023	—·0002	—·0002	·549	·00007	·00008	2,100	8,000	Vertical cracks just outside each load point
						·459	·00012	·00010	3,600	9,700	
						·392	·00020	·00013	6,000	11,500	
253,000	0·13	·017	·030	—·0002	+·0002	·379	·00025	·00018	7,500	13,400	
285,000	0·17	·019	·037	—·0003	+·0004	·326	·00035	·00019	10,500	15,300	
317,000	0·18	·021	·044	—·0004	+·0003	·289	·00049	·00020	14,700	17,400	More cracks outside of load points
						·263	·00059	·00021	17,700	19,300	
350,000	0·24	·024	·050	—·0005	+·0002	·265	·00067	·00024	20,100	21,400	
382,000	0·28	·028	·057	—·0006	·0000	·273	·00077	·00029	23,100	23,300	
414,000	0·31	·032	·064	—·0004	+·0003	·280	·00086	·00033	25,800	25,300	
447,000	0·36	·037	·070	—·0001	+·0011	·300	·00093	·00040	27,600	27,300	Marked diagonal cracks
						·330	·00098	·00048	29,400	29,300	
500,000	0·40	·043	·075	·0000	+·0014	·326	·00106	·00051	31,800	31,400	
514,000	0·43	·046	·081	+·0007	+·0021	·324	·00123	·00059	36,000	35,300	
578,000	0·52	·053	·094	+·0023	+·0045	·334	·00140	·00070	42,000	39,300	
643,000	0·61	·062	·107	+·0047	+·0079	·335	·00159	·00080	47,700	42,900	
704,000	0·70	·071	·122	+·0083	+·0119	·306	·00204	·00096	61,200	47,600	
780,000	0·88	·084	·156	+·0138	+·0152	·271	·00360	·00132	108,000	49,600	
811,000	1·32	·132	·270	+·0170	+·0181						Tension cracks opening wide
840,000	1·66	—	—	—	—	† Add 2,800 lb. per sq. in. for stress due to weight of slab.					Maximum load. Tension failure

* This load of 25,000 lb. is assumed as the weight of testing apparatus and men and the initial tension of rods. After jacks were in operation all but 9,000 lb. was indicated by readings of the gauges.

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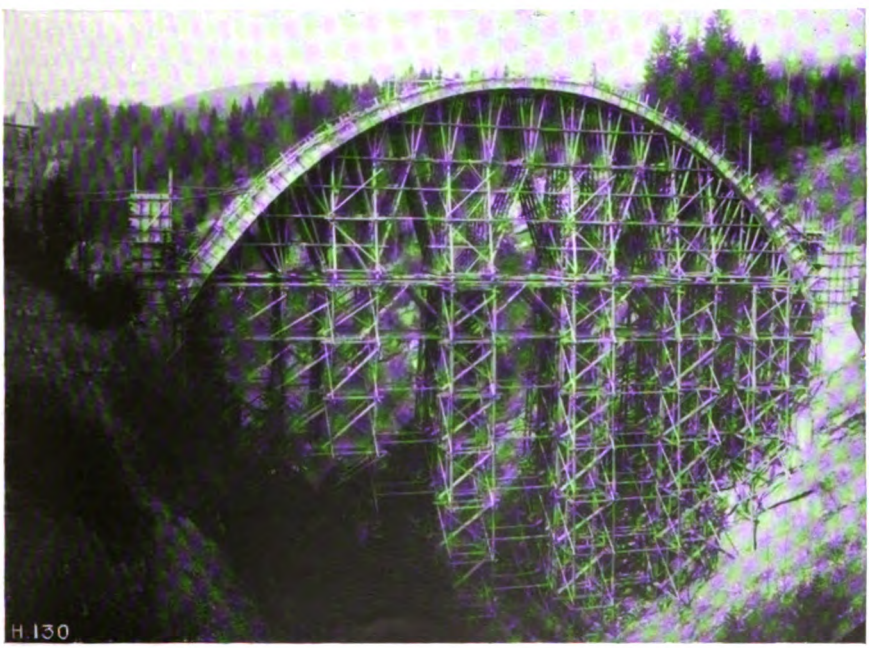
General Conclusions.—In conclusion, Prof. Talbot remarks that, as these particular slabs may be presumed to be fairly representative of the slabs fabricated for the work, the tests ought to add confidence in the quality and soundness of the reinforced concrete used in this work and in other work of large magnitude made under as careful conditions. He also points out that the action of the concrete in compression under the high stresses developed was quite satisfactory, and that the tests show the effectiveness of stirrups and of the methods used in bending up bars at the ends in resisting diagonal tension, and also that it seems evident from these tests that the action and properties of reinforced concrete beams made under efficient supervision do not differ much from those of laboratory test beams. The concluding remarks on these tests should be borne in mind by all designers of reinforced concrete structures. The Professor says: "Diagonal tension weakness is particularly undesirable because of the possibility of sudden failure, and of injury after repeated applications of the load, and because of the difficulty of detecting incipient failure when the sides of the beam are not available for inspection. Ample safety against these conditions is important, and means should be provided to resist the diagonal tension."



A Reinforced Concrete Bridge in Switzerland.

Fig 3. Showing Centering from a different position.

(*See page* 190.)

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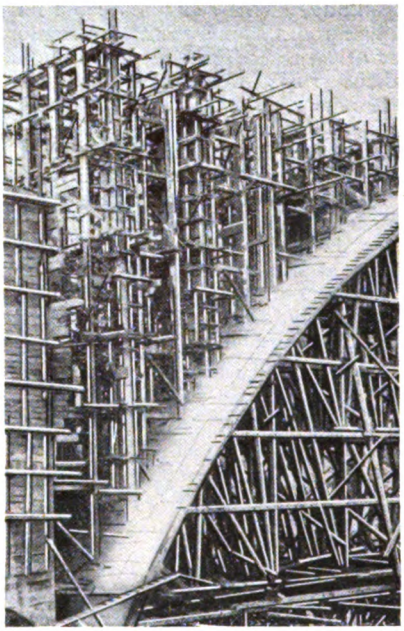

FIG. 4. TIMBERING ABOVE ARCH.

REINFORCED CONCRETE BRIDGE NEAR TEUFEN.

(Switzerland.)

By WILLY OBRIST, St. Gallen.

(Free Translation from the German.)

So much is being written regarding the advisability of using reinforced concrete for bridges that we herewith present an example of a reinforced concrete bridge in Switzerland, where the material was selected specially to save the heavy cost of maintenance met with where steel bridges are used in Switzerland.

The data were obtained on the spot by the author, an article by Prof. Mörsch in the "Schweiz. Bauzeitung," 1909, Vol. 53, also being used.—ED.

THE iron road bridge erected at the above place in 1856 having proved insufficient for the traffic, it was necessary to alter it or to replace it by a new structure. It was decided to build a new bridge, and since the cost of a steel bridge would have been

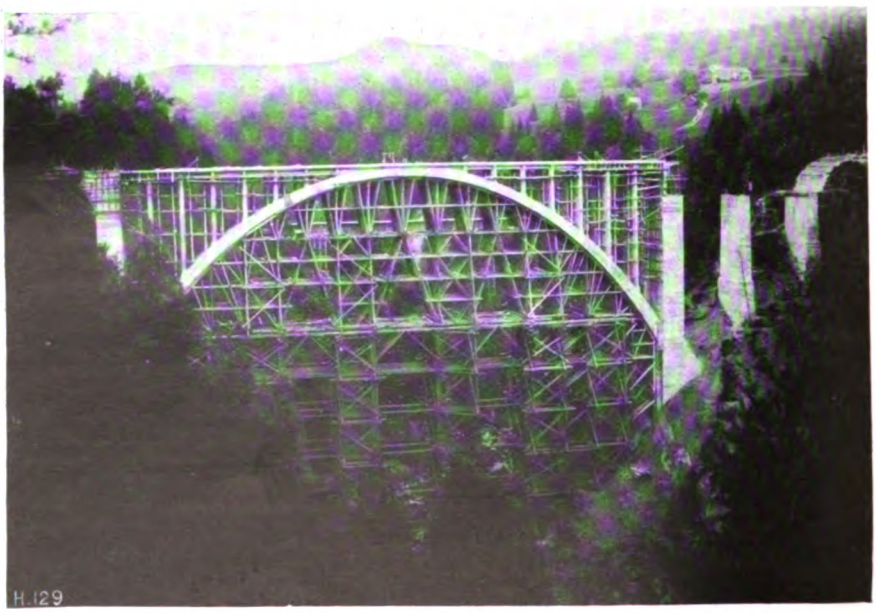

FIG. 2. THE FINISHED REINFORCED CONCRETE ARCH.
(The railway can be seen through the centering near the apex of the arch.)

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almost as high as that of one in reinforced concrete, the latter mode of construction was adopted with the view of saving the heavy maintenance charges.

The new bridge crosses the Sittertobel in one large arch, 79 metres (259 ft. 2 in.) span and 26·5 m. (87 ft.) rise. This is succeeded on the left bank by four arches 10·25 m. in span (33 ft. 7 in.), and on the right bank by two such arches (*Fig.* 1).

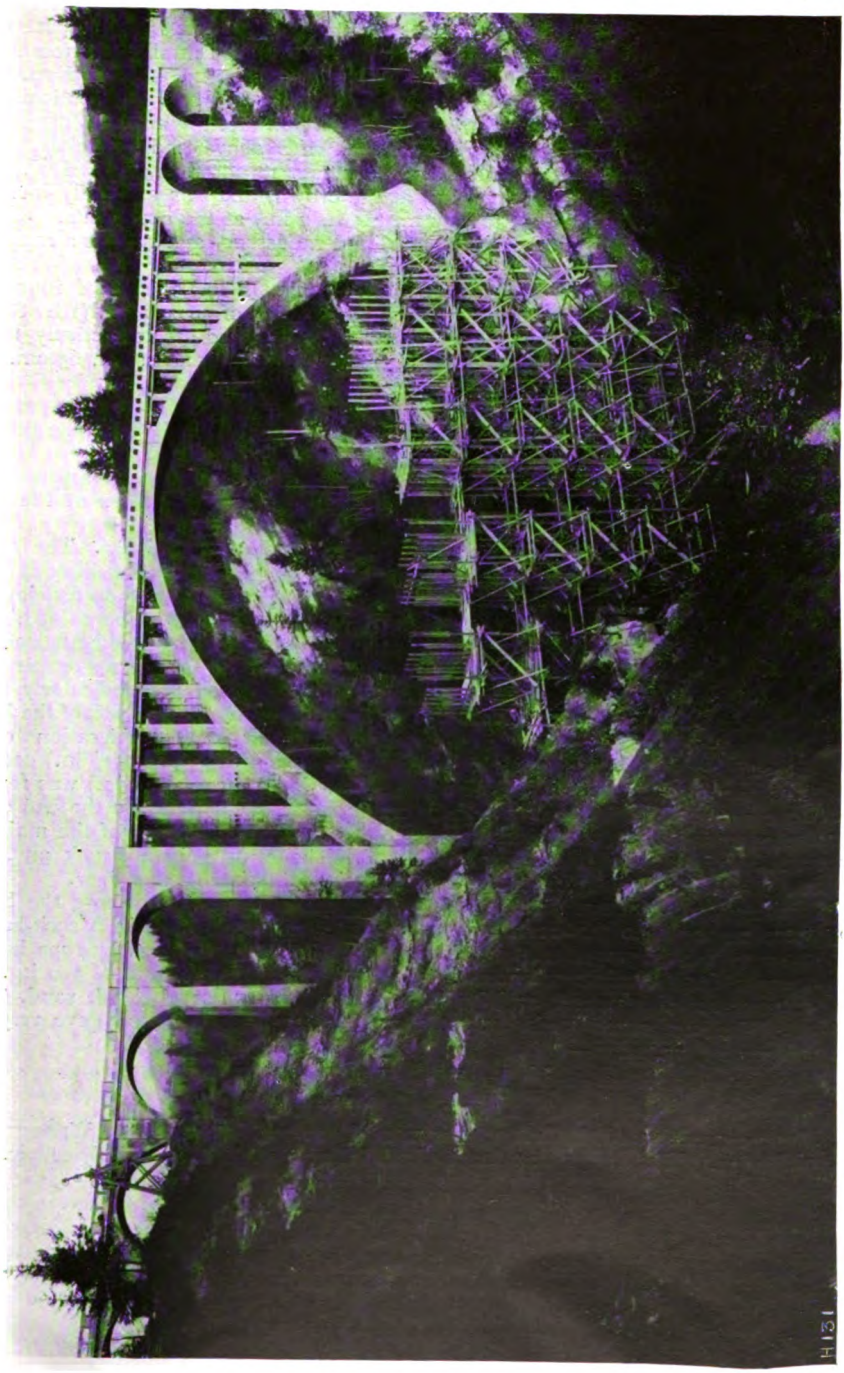

FIG. 1. VIEW OF THE REINFORCED CONCRETE BRIDGE, LOOKING DOWN THE RIVER.

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The roadway is about 66 m. (216 ft. 6 in.) above the level of the river, and has a width of 6·9 m. (22 ft. 7 in.) between the parapets, including two footpaths each 60 cm. (23½ in.) wide. The main span is treated as an arch with fixed ends and without hinges. As live load, a steam roller of 20 tons weight and a crowd amounting to 450 kg./m² (92 lb. per sq. ft.) were considered, provision also being made for a variation of temperature of ±20° C. (±36° F.). The form of the arch is that of the curve of equilibrium for the dead load. The thickness at the crown being 1·20 m. (3 ft. 11 in.) and at the abutments 2·13 m. (6 ft. 11 in.), the maximum and minimum stresses were calculated to be 31·3 and 0·4 kg./cm.² (445 and 5·7 lb. per sq. in.). Although no tensile stresses should theoretically occur, yet in order to secure a proper distribution of the loads due to the spandrel columns, the arch was reinforced with rods of 28 mm. (1·1 in.) dia. there being at the crown 10 such rods above and 18 below, in the quadrants 14 above and below, and at the abutments 18 above and 10 below. The breadth of the arch is 6·5 m. (21 ft. 4 in.) at the crown, and this gradually increases, in order to secure lateral stability, to 7·50 m. (24 ft. 7 in.) at the abutments.

The foundations are in interstratified marl and sandstone, and sustain a maximum load of 6·5 kg./cm.² (92 lb. per sq. in.).

The roadway consists of a reinforced plate 20 cm. (8 in.) thick and four longitudinal beams, and is supported from the arch by columns of 50 × 50 cm. (1 ft. 8 in. × 1 ft. 8 in.) section. The beams are treated as continuous, and are respectively 1·49 m. and 1·37 m. (4 ft. 10 in. and 4 ft. 6 in.) apart, 4·5 m. (14 ft. 9 in.) span, 65 cm. (2 ft. 2 in.) high, and 25 cm. (10 in.) broad.

The connection with the main columns is made by means of a so-called "pendulum wall," 25 cm. (10 in.) thick, the elasticity of which allows it to follow all the deformations of the roadway due to changes of temperature.

The smaller arches are also so formed that only compressive stresses occur; all are reinforced with five rods of 14 mm. (0·55 in.) dia., the thickness at the crown being 35 cm. (14 in.).

The centering used was a model of its kind (see *Figs.* 2 and 3). The timbers were so arranged as to be subject only to compression, all loads being directly borne. Channel irons were placed between the vertical and horizontal timbers to distribute the loads. The six ties, 1·4 m. (4 ft. 7 in.) apart, were bedded on sand boxes at a height somewhat above the springing of the arch. As the timbering stood without load from December, 1907, to the following March, it was necessary to provide for proper resistance to wind-pressure. Special struts were therefore placed perpendicularly to the ties, supported below at 10 m. (32 ft. 10 in.) to the right and left of the axis of the bridge.

The good construction of the centering is clear on consideration of the deflections observed. During the concreting a depression of 32 mm. (1¼ in.) occurred, and on removal of the centering a permanent deflection of 5 mm. (3/16 in.) was found.

The construction of the work was begun in March, 1907, and by the end of that year the centering and foundations were completed. The concreting of the main arch occupied from March 26th to May 16th, 1908. The centres were struck on August 1st, and the bridge was taken over on November 7th of the same year.

Sand and gravel were obtainable from the bed of the stream above the bridge; they were conveyed to the work by rope haulage, and broken up in a rock-breaker. The concrete was conveyed to the point at which it was to be used by rope haulage. The concrete for the reinforced portions was composed of a mixture of 300 kg. Portland cement, 420 litres sand, and 840 litres gravel (1 yd. gravel, ½ yd. sand, 600 lb. cement). The test cubes made from the same concrete as the arch gave very high strength results, namely:—

After 28 days	305 kg./cm.²	(134 tons per sq. ft.)
3 months	395 ,,	(173 ,, ,, ,,)
6 ,,	447 ,,	(197 ,, ,, ,,)

The construction of the bridge was carried out by Messrs. Froté, Westermann & Co., of Zürich. The design was due to Prof. Mörsch, of the Zürich Polytechnic.

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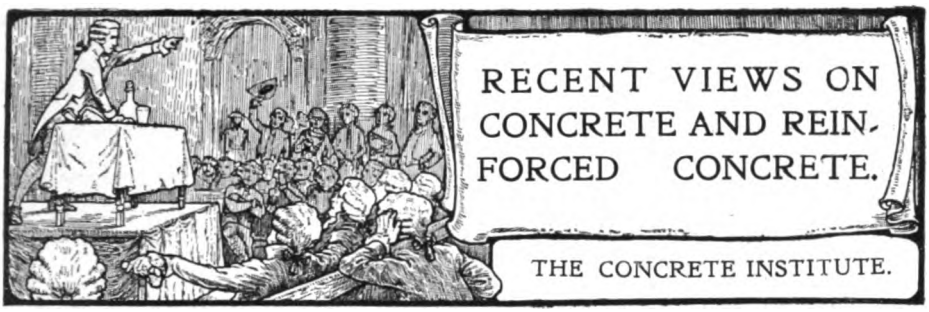

It is our intention to present the Papers and Discussions of the Concrete Institute in a concise form, and in such a manner as to be easily available for reference purposes.
The method we are adopting, of dividing the subjects into sections, is, we believe, a new departure.—ED.

How interesting the discussion on a practical paper may become will be seen from the fact that two meetings of the Concrete Institute had to be devoted to the presentation and discussion of Mr. H. K. G. Bamber's paper on "The Setting of Portland Cement." The paper and the discussion were of quite exceptional importance.

It is to be hoped that this active interest in all phases of the subject of concrete, reinforced concrete, and its constituents may continue and see yet further development.

THE SETTING OF PORTLAND CEMENT.

PAPER by H. K. G. BAMBER, F.C.S.
Managing Director, Associated Portland Cement Manufacturers (1900), Ltd.

Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., Member of the Council, presiding, opened the proceedings by announcing that the roll of members and subscribers of the Concrete Institute at the date of the meeting exceeded 700.

The Chairman then asked Mr. Bamber to read his paper.

MR. H. K. G. BAMBER, F.C.S., Reader of the Paper.

THE author began by stating that his object in writing the paper was to give to the members of the Concrete Institute a short *resume* of some of the results of research work in this direction done by manufacturers and others, more especially as applied to the more modern methods of manufacture.

He purposely gave the practical side of the question the pride of place, as the interests of the members of the Concrete Institute, and in fact all users of cement, were more concerned with this branch of the investigation than with the other. It mattered little to them what the exact formula might be representing the composition of the ingredients and their combination in the finished product so long as they had at their command a material which could be used under all conditions of their work, and positive information from the practical results of competent investigators in this field of inquiry as to the best methods to be adopted by the engineer and other users to insure successful work in the sometimes difficult conditions under which this work had to be carried out.

He did not propose to express any new theories, but in order that it might be seen how indefinite the present real scientific knowledge of this difficult subject was, and what insufficient and contradictory data the cement manufacturer had at his command when embarking on any practical experiment based on scientific theories, Mr. Bamber shortly referred to those which existed, and were most accepted at the present time.

Lime Percentage.—It was well known that for the best cement the total percentage of lime (CaO) present, as found by analysis after decomposition of the various silicates and aluminates by solution and subsequent separation, was confined to very narrow limits—*i.e.*, 63.5 to 65 per cent. The amount of silica (SiO_2) varied from 21 to 23.5 per cent., and alumina (Al_2O_3) from 5 to 6 per cent., so that whether the ration of lime to silica was calculated on a percentage basis or in accordance with chemical equivalents, it approximated 2.8 parts lime to 1 part silica, the formula for which, without assuming any definite combination, might therefore well be written as $3CaO\ SiO_2$, leaving approximately the lime required in combination with alumina to form dicalcic aluminate, and any attempt to vary this ratio to any extent resulted in a material which had not the good properties of, and could not be designated as, a true Portland cement.

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The percentage figures he had mentioned of 63·5 to 65 per cent. of lime might appear to many who were accustomed to the old specifications for cement, placing a maximum of 61·5 per cent. for lime, to be high, but many analyses of pure clinker taken from such kilns as were used for the old methods of manufacture, and which were presumably producing cement within that apparently low limit, showed that for years the higher figure had been the percentage in all good cement clinkers, the actual fact of its presence in such quantities in the ground cement in part being cloaked by the accidental introduction of extraneous foreign matter derived as an uncombined residue from the fuel used for calcination.

These facts were mentioned, as they had an important bearing on the setting properties of cement.

Setting Theories.—Like the constitution of Portland cement, the theories as to the setting were also somewhat vague and uncertain; but it was generally assumed that the action was brought about firstly by the hydration upon the addition of water and subsequent crystallisation of the calcium aluminates present, which occurred with great rapidity, constituting what was known technically as the "initial set," causing cohesion of the mass of cement and the intermingled aggregate. This was followed by the hydrolysis of the calcium silicates, the latter being slowly decomposed and broken down into the more simple form of mono-calcium silicate, with the consequent liberation of calcium hydrate ($Ca\ OH_2$), which being in excess of that required to form a saturated solution partially crystallised out—this cycle of operations continuing over long periods during the hardening of cements.

The Colloid Theory.—Mr. Bamber also mentioned the colloid theory of Michaelis, which the latter described as his "gel-theory," and in which he held that vitrified cement, when mixed with water, dissolving some of the lime from the cement, swelled and formed a gelatinous or colloidal substance of calcium hydro-silicate, which, solidifying, constituted the hydraulic hardening process.

In a paper read in Berlin in 1907 he said: "Upon the existence of the hardening and solidifying colloids, created during the hardening process of all calcareous hydraulic cements, depends their durability in water. The formation of a solidified colloid as the chief element of the hydraulic cements is the characteristic and only essential feature of the hydraulic hardening process. . . . When water acts upon silica oversaturated with lime, as in Portland cement, colloids are formed, and it is of no consequence whether there are 1, 2, 3, 4, 5, or 6 molecules of calcium oxide present for each 4 molecules of silica; in all cases colloidal calcium hydro-silicate is formed. . . ."

These, then, were the hypotheses, correct or incorrect, which guided the cement manufacturer embarked on a field of investigation, or with which he endeavoured to explain the various phenomena which presented themselves from time to time during the course of manufacture.

The time allowed for consideration of these matters would not permit of a complete exposition of the many problems that confront the manufacturer, and it was proposed, therefore, on this occasion, to deal only with some of the points that arise in connection with the retardation of the setting time in order that the latter might be brought within reasonably controllable limits, and to endeavour to explain the irregularities that were sometimes found when testing the setting time and the soundness of present-day Portland cements.

Cement Clinker.—A thoroughly well-made Portland cement clinker, ground to normal fineness, was always very quick setting, almost equal to that of plaster of Paris, but this property of rapid-setting could be somewhat delayed by mixture of other foreign substances, as was done accidentally until recent years, and, in fact, yet continued, with cement manufactured on the intermittent kiln system, now being rapidly superseded. By this method dry material of uniform and correct composition was calcined by mixture with from 40 to 45 per cent., or even more, of its weight of coke and coal, the ash from the fuel—about 12 to 15 per cent. of the weight of the fuel used—remaining mixed up with the calcined clinker. In most cases this foreign matter alone had the effect of prolonging the setting time some few minutes, but portions of the clinker removed separately and free from the fuel ash when ground to powder set almost instantaneously upon the addition of water, with disengagement of considerable heat due to the rapid chemical action.

It was difficult to satisfactorily explain why the admixture of the fuel ash should have the effect of retarding the setting time somewhat, unless it was that it contained an amount of sulphates derived from the oxidised sulphur compounds originally present in the fuel used, and these sulphates having a similar effect on the cement as the addition of a similar amount of gypsum—or it might be that owing to the less perfect burning of cement in the past cement always contained free lime in the amorphous, as distinct from the crystalline condition—this lime being quickly dissolved in the water used for gauging, which, becoming saturated, prevented the solution of the calcium aluminates, and thus somewhat retarded the set.

Rotary Kiln Clinker.—During recent years, and upon the introduction of new methods, more particularly that of the rotary kiln, none but this pure character of clinker was produced, containing practically no free lime in the amorphous condition—the system being such that the ash from the fuel, the latter in quantity being in itself at least 33 per cent. less, to a very large extent passed away with the effluent gases from the kiln. This also applied largely to the sulphur compounds in the raw

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material and coal, which, being decomposed, passed out of the kiln as sulphurous acid with the other gases. The clinker thus produced was practically pure, and resembled those portions of picked uncontaminated clinker from the intermittent kiln previously referred to, and, like that, had, when finely ground, an almost instantaneous set, and with a lime content on analysis in both cases ranging between 64 and 65 per cent. It was thought that cement manufactured by the rotary process had a quicker initial set when untreated with any addition for the purpose of retardation than had the cement made by the older process, but this had been found to be an entire fallacy, since it was found that the pure uncontaminated clinker from an intermittent kiln was equally as quick setting as the pure clinker from the rotary kiln, the similarity being cloaked by the presence of the foreign matter from the fuel in the older process cement

Modern Manufacturing Process.—The realisation of these facts was not apparent in the early days of the more modern methods, and the manufacturer was faced with what appeared to him at first to be a new difficulty, whereas in reality it was the obvious result of the more careful production of a pure material, which he had been accustomed formerly to manufacture accidentally in a more or less contaminated condition. In ignorance of the above facts it was thought that perhaps the rapidity of the modern manufacturing process—more particularly the cooling down from the higher ranges of temperature of the calcined clinker, which was accomplished in a few minutes after reaching the maximum temperature—might be the cause of the apparently more chemically active condition of clinker manufactured by the rotary process; and very elaborate and costly experiments were carried out, extending over a long period in which the calcined clinker after passing the clinkering temperature was kept at a red heat for a considerable time before final cooling, imitating, it was thought, the slower action of the old intermittent kiln process.

Experiments.—Unfortunately, like many others, this experiment, although carried out on a practical and commercial scale, either through the difficulty in regulating the supplies of clinker to insure a steady temperature of cooling, or through mechanical difficulties which the operation presented, was of a negative character.

Previous laboratory experiments in this direction had given great promise that more useful results might have been obtained, and undoubtedly indicated that during the calcination of cement clinker there are critical points of temperature of great importance, and well worthy of the careful study of the scientific specialist.

Experiments were also carried out to test the concentrated action of carbonic anhydride upon these various aluminates, this being the principal ingredient in the atmosphere which, together with water, brought about the natural process of aeration of cement. It was found that the aluminates containing the higher proportion of lime were less effected by this treatment with CO_2 than the lower aluminates, which it was thought might be the explanation why rotary cement was less affected by exposure to the atmosphere than cement made in intermittent kilns.

Research Work.—A very considerable amount of research work was done under the author's supervision in connection with the properties of the various calcium aluminates, to which the quick setting property of Portland cement was attributed. As already explained, it was thought that the more rapid cooling of the clinker probably had some chemical or physical effect on the aluminates present, and in order to test this theory the dicalcic, tricalcic, and tetracalcic aluminates were synthetically prepared in order if possible to test their setting properties individually when rapidly or slowly cooled from the state of fusion.

Unfortunately, such investigations were replete with difficulties, and it must not be forgotten that in examining these isolated components of cement their assumed properties when in a pure state might be entirely altered by the presence of other ingredients in cement reacting one upon the other. On the whole, the results in this line of research were of a negative character, but the author mentioned this series as one of many such experiments carried out to indicate the highly scientific class of investigation the cement manufacturer was prepared to undertake to obtain a further knowledge of the properties of the material the manufacture of which was under his control.

Attempts had also been made to reduce the quantities of aluminates present by adjusting the composition of the raw materials, by increasing the silica content at the expense of alumina; but here again only partial success was met with, as it would appear that even small proportions of calcium aluminate present were sufficient to cause a very rapid initial set of the whole mass; in fact, as far as the author was aware, in no case, even where the raw materials were such that the calcined clinker contained a high percentage of silicates and a low percentage of aluminates, was the initial set of such cement, untreated with retarders, other than very rapid—in fact, almost instantaneous.

Gypsum.—In order to avoid the necessity for the addition of gypsum to the calcined clinker, which until water was added to the cement was present only as a mechanical mixture, it was thought that this addition might be made to the raw material previous to calcination, during which operation it might become evenly incorporated with the whole mass of clinker, but in practice this was found to be quite inoperative as at the maximum temperature of the kiln in the presence of silicates, etc., gypsum incorporated with the raw materials was decomposed, the sulphuric anhydride (SO_3) being

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evolved and passing out of the kiln with the other gases, the remaining lime (CaO) combining with the silicates (clay); the added calcium sulphate in this case only having the same function as the calcium carbonate present, which gave up its carbonic anhydride (CO_2), which escaped from the kiln, leaving the remaining calcium oxide (CaO) to combine with silica and alumina (clay).

Other Methods.—Various other suggested methods of prolonging the setting time of cement without having recourse to the mechanical addition of retarders to the finished cement had been attempted, such as the injection of solutions of the alkalies and alkaline earths, and such like, upon the hot clinker during its passage through the cooler, but all these had met with only limited success, the results obtained being in many cases evanescent, and in others creating further mechanical difficulties in the grinding of the clinker, which rendered such processes physically and commercially undesirable.

Calcination.—At the end of the nineteenth century practically all the cement manufactured in the United Kingdom and in Europe was produced by the old method of calcination in intermittent or somewhat similar kilns, the product being a clinker having various degrees of hardness, ranging between the material thoroughly calcined at a temperature above 2,800° Fahr. (at which temperature a thoroughly chemical combination has taken place), and the material technically known as "half-burn," which latter was practically the raw material from which only the carbonic anhydride of the chalk or limestone and the water of hydration and organic matter of the clay had been expelled. Now it was quite easy to realise, seeing the very complex character of the chemical combinations which were thought to take place at the true temperature of calcination, how difficult, and, in fact, almost impossible, it must be to determine a formula which will correctly represent the chemical composition of even a uniform raw material calcined under such a wide range of temperatures as that represented by 2,800° and 900° Fahr., at which latter temperature the volatile matters from the raw materials were expelled.

Physical Conditions.—It was equally easy to realise that the physical conditions, and therefore the setting properties of the atoms forming this heterogeneous mixture, must be of a very varying character, depending largely upon the relative proportions of the heavy or more lightly burned clinker, or that of an intermediate character, present in the mass as removed from the kiln; the more heavily burned portions were considered the most valuable, more especially those portions of clinker which had not been contaminated with or fused by contact with the siliceous matter contained in the ash of the fuel; and the product of the present-day rotary kiln, calcined in small particles at a uniform temperature and in the absence of fuel ash, consisted, as one would expect, almost entirely of this pure clinker. The only methods known to the ancients of retarding the setting time of this heterogeneous mixture of silicates and aluminates was by exposing such cement after grinding to long periods of aeration or by the addition of gypsum in one form or other.

Prolonged Aeration.—The first process was only successfully applicable in the absence of added gypsum, and the effect of prolonged aeration of such cement was the absorption by the uncombined lime and the loosely combined silicates and aluminates, etc., of water derived from the moisture in the atmosphere, and subsequently carbonic anhydride from the same source. In this manner a considerable quantity of the material became carbonated and inert, depriving the cement of a not inconsiderable portion of its former chemical activity, and thus causing a prolongation of the setting time.

It would be seen that such method must be most imperfect in its action, and required a considerable length of time to enable the moisture and the carbonic anhydride in the atmosphere to find its way into the interior portions of the heap, by which time the outer portions would be considerably over-aerated and become practically inert.

Atmospheric Action. — It would seem that the action of the atmosphere was confined to the loosely combined or lightly burned particles of the cement, and that the thoroughly calcined particles were little affected by exposure to the atmosphere at normal temperatures, and this experience seemed to be confirmed from the fact that cement manufactured by the rotary process, producing the pure clinker, when ground without treatment or additions to retard the setting time, would retain its original quick-setting property unimpaired for long periods when stored in bulk. Instances of this had occurred where cement, having an almost instantaneous set at the time of manufacture, had retained this property when kept in bulk, but otherwise exposed to the atmosphere, for a period of two years.

It would be seen from this that the old method of simple aeration in bulk to retard the setting time could not be applied with any degree of the former success to the product from the rotary kiln, and this would also seem to be evidence that the cement manufactured by the more modern process was of a much more stable and reliable character than that formerly put upon the market. A cursory examination of the clinker produced by the two methods would, even to the uninitiated, be sufficiently convincing on this point.

Aeration Methods.—In view of the fact that this simple method of aeration in bulk could not be successfully applied to cement manufactured on the new system, many attempts were made to accomplish the most important part of natural aeration—*i.e.*, the absorption of water, by artificial

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means, such as passing the ground cement through a moist atmosphere, or by blowing moist air through the cement in bulk. These methods, however, were not found to be wholly successful—firstly, from the physical and mechanical difficulties which presented themselves by reason of the partial setting of the finest portions of the cement, with the consequent blocking of any apparatus used for the purpose, such as revolving drums, distributing discs, conveyor screws, and scrapers, and the like; and, secondly, in the author's opinion, for the much more important reason that, in order to accomplish the desired result in a short space of time, it was necessary to submit the cement manufactured by the rotary process (all of which consisted of finely reduced particles of the pure calcined clinker) to a moist atmosphere at a comparatively high temperature, as distinct from the normal temperatures under which all the previous attempts at artificial aeration had been carried out.

"Tube Mills."—In order that this might be accomplished, and the cement submitted to a moist atmosphere at a high temperature, in which the action of the water vapour upon the particles of clinker might be rapid and effective, a process was introduced in which advantage was taken of the peculiar construction of the mills chiefly used for completing the reduction of the cement to a fine powder in enclosed revolving cylinders, known in the trade as "tube mills," which contained as their grinding media a heavy charge of steel balls or flint pebbles.

Tube Mill Experiments.—The cement introduced into these mills for the purpose of finishing was in a coarsely ground condition, having previously been dealt with by some form of preliminary grinder, during which process, owing to the friction entailed, the temperature of the material was raised to a point ranging between 140° and 160° Fahr. The friction due to the action of the attrition of the steel balls or flint pebbles against themselves, the sides of the mill, and the passing cement, caused the temperature in the tube mill to be still further increased, and it was at this point where moisture was introduced in the form of a regulated supply of steam, which still further increased the temperature and enabled it to be maintained at a point above 180° Fahr., preferably about 200° Fahr., at or above which temperature the operation is most successfully conducted, and the cement operated upon was made to take up uniformly throughout an amount of water, in practice about 1 per cent. or a little under, with which it combined chemically, and which could not be expelled except by ignition.

The thoroughness of the process will be realised when it was understood that the time of passage through the tube mill was about two hours, and that each particle of cement was being continuously submitted for that period of time to a moist atmosphere acting upon its surface, which latter was removed by the attrition of the balls or pebbles, exposing a fresh surface upon which a similar action took place, until the whole left the mill at a temperature which had been gradually increasing until the operation was complete. In this way the operation of exposure to moisture was accomplished at a temperature above the critical point necessary for the purpose, and in such a manner that no mechanical difficulties presented themselves in the blocking of the machinery or apparatus.

The facts mentioned in reference to the importance of carrying out the process at or above a certain temperature were not generally known.

Adding Gypsum.—Now let them return to the other method of retarding the setting time known to the ancients—*i.e.*, the addition of gypsum to the product of the intermittent kiln during or after the process of grinding.

With this class of cement, containing already sulphates equivalent to about 1·5 per cent. SO_3, derived, as previously stated, from the sulphur compounds in the fuel, it was generally sufficient to add 1½ per cent. of gypsum to obtain a slow-setting cement; the effect, however, in most cases was only transient, as it was well known that the effect of aeration, even when the cement was packed, almost invariably resulted in such cement returning first to its original quick-setting condition before subsequently becoming slow setting, and largely inert through excessive exposure to the atmosphere. This peculiarity of cements slowed by gypsum had been the cause of much difficulty to the manufacturer, and many conflicting theories were propounded as to the cause of such reflex action.

Slow-setting Cement.—A hydrated slow-setting cement containing 0·95 per cent. of SO_3, of which only 0·35 per cent. was added, retained this property of slow setting for long periods in commercial packages, as it was also known to do when stored in bulk.

It was difficult to give any definite chemical or physical explanation of the fact that the presence of as little as 1 per cent. of combined water in cement, which had been taken up at a high temperature, should not only in itself have the effect of appreciably slowing the setting time, but that when present in conjunction with even small percentages of gypsum the slowing effect of the combination was maintained.

The presence of 1 per cent. of combined water had also an enormous influence on the action of cement when tested for soundness under the boiling test, more particularly under the method invented by Le Chatelier and now usually adopted, by which method and with which apparatus it was thought the actual expansion of the cement could be measured.

By means of the steaming process described the proportion of gypsum required to be added to produce a slow-setting cement was much reduced, and if advantage were taken of the greater solubility

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of plaster of Paris ($CaOSO_3$ $\frac{1}{2}H_2O$) over that of raw gypsum ($CaOSO_3$ $2H_2O$) the quantity of SO_3 introduced into a cement might be reduced to a minimum.

Gypsum Effects.—The author had referred to this subject on former occasions. Inasmuch as the effect of gypsum in retarding the initial set of cement depended upon the rapidity of solubility in the period immediately after the addition of water, and the quantity that could quickly be brought into solution (in which condition it was alone active), it followed that the form of gypsum having this property most developed would be the most effective. The quantity required to produce like results when plaster was used might be one-third less than with gypsum, and this was important in view of the known defects produced by the addition of gypsum to cement, more especially if the cement was to be deposited under water (more particularly sea-water) before setting commenced.

Le Chatelier's Test.—Le Chatelier, in a paper read at the meeting of the International Testing Association at Brussels, describing the behaviour of cements in sea-water, said: "By introducing important quantities of calcium sulphate into hydraulic cements, it is possible to bring about their disintegration at more or less rapid speed; and, as a rule, destruction proceeds faster when the material is in the sea than when it lies under fresh water.

It was important, in view of the chemical action which was said to take place between the added sulphate of lime (gypsum) or the soluble constituents of sea water, with the aluminate of lime in the cement, forming a compound said to be sulpho-aluminate of lime, that the amount of added gypsum should be kept as low as possible.

The action referred to by Le Chatelier was continually in evidence with all cements to which more than 2 per cent. of gypsum had been added to retard the setting time, when such cements were tested by the accelerated methods for determining the ultimate soundness, more particularly when they were subjected to the primary stages of that quantitative boiling test which appeared in most specifications, introduced by Le Chatelier himself, and which bore his name.

This test was designed with the object of detecting rapidly any inherent unsoundness in cement, so that a knowledge as to the constancy of volume of any cement might be obtained previous to its use in the work.

To those who had much experience in the orthodox working of this apparatus it was apparent that the conclusions drawn might frequently be entirely fallacious, and many perfectly sound cements thereby rejected, while others of doubtful quality for certain conditions of work were not detected.

Expansion.—In adopting this test the fact seemed to have been entirely overlooked that many cements, more especially those containing over or about 2 per cent. of gypsum, were found to expand considerably during the primary immersion in cold water and might show but a slight further expansion during the second, or boiling, stage of the operation. Such cements would be passed as satisfactory by this test, and no doubt many would prove to be so, if allowed to harden before immersion in water. It would seem, however, that as at present conducted the test entirely failed to detect (unless a record of the expansion during the cold water immersion was included) a cement containing an unsafe percentage of gypsum, which cement might be required for work where the concrete was of necessity deposited under water immediately after gauging.

The period of immersion before boiling stipulated in the Le Chatelier test was a very important factor in affecting the results, and appeared to be entirely arbitrary. It might be that certain cements, perfectly sound in cold and in boiling water, and especially those of a very slow-setting character, would fail to pass if boiled 24 hours after gauging, whereas at 36 or 48 hours, or even longer, the results might be perfectly satisfactory.

Causes of Expansion.—Now as to the causes of expansion of certain cements when boiled, this might be due to (1) an insufficient reduction and amalgamation of the raw materials; (2) incomplete or irregular calcination; or (3) a predominance of small unground particles of clinker in the finished cement. The Le Chatelier test was designed to guard against the results of such irregularities in the course of manufacture, and as regards points 1 and 2, was useful and effective, as unsoundness due to either of these causes might subsequently develop, causing disintegration. The expansion under these circumstances was probably due entirely to chemical causes, resulting either from unbalanced proportions of the raw materials, possibly also in an unsuitable mechanical condition, refusing to form during calcination a chemical combination of the same uniform character as would be the case if chemically balanced and thoroughly amalgamated; or, given a satisfactory raw material in all respects, the expansion on boiling might be due to the fact that during calcination the raw material, either wholly or in part, might not have been brought up to the requisite temperature at which the principal compounds constituting Portland cement were formed.

Unground Particles.—The expansion, however, due to the third cause—*i.e.*, the presence of unground particles of well manufactured clinker, came under a different category, for the material causing expansion was of identical composition, and had the same chemical and physical properties as the finer-ground portions of the cement, which latter, *per se*, were entirely free from expansion when boiled. The cause in this case was rather more of a physical character than a chemical one, although it must be admitted that the hydration of the particles of clinker at the high temperature, which in the author's opinion was the cause of the expansion in this case, was a chemical process.

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It was evident that the mere reduction of the clinker to a fine powder did not in any way change the chemical composition of the cement, and if any difference was noticeable under the Le Chatelier boiling test between a finely ground and the same coarsely ground clinker, the former being perfectly sound and the latter showing expansion, this expansion must be due to the action of water at a high temperature on these particles.

Conclusions.—In the author's opinion the conclusions drawn from the results of tests under the Le Chatelier method, brought about through this latter cause, might be misleading, because it was assumed that these particles causing expansion consequent upon hydration at a high temperature would equally expand at normal temperatures, which had yet to be proved.

From experiments it would appear that the larger particles of clinker remaining even in a commercially finely ground cement, which were hydrated with expansion when in contact with boiling water under the Le Chatelier test, were also hydrated, and perhaps also with expansion, by contact with steam at a high temperature, although in a comparatively dry condition, during the process of grinding.

This would seem to be the logical reason of the fact that while cement manufactured from clinker chemically well balanced and thoroughly calcined would expand when submitted to the Le Chatelier test, it would not expand under the same conditions if it had been previously treated by the hydrating process.

Futile Methods.—Attempts had been made to use other materials for regulating the setting time, such as calcium chloride, sodium carbonate, etc., etc., but as far as the author was aware these methods have not proved commercially successful. At the present time the processes employed were practically confined to watering the clinker hydrating by means of steam during grinding, and the addition of gypsum. With these methods individually, or with a combination of same, cement could be produced having setting times suitable for all requirements.

Although the methods described made it possible to produce cement with definite setting properties, it must be remembered that the activity of the chemical process of setting was dependent upon the hygroscopic condition and temperature of the atmosphere or surrounding conditions under which concrete work was being carried out, a high temperature and a dry atmosphere tending to increase the rapidity of the set, and *vice versa*.

Conclusion.—Some tests indicating the change in the character of the setting time of cement due to temperature and atmospheric conditions, over which the manufacturer had no control, and which will always exist, were then referred to by the author, who thought their results should induce the engineer, architect, contractor, or other users of cement to supply the manufacturer with the fullest possible detail of the prevailing conditions under which the cement he purchased is likely to be used, so that the experience of those who have made this question a special study might be utilised to the full, and by the avoidance of failures thereby creating even greater confidence in the method of concrete construction, which, although developed of recent years to an enormous extent, was yet in its infancy.

The Chairman then called upon Mr. Bertram Blount, Member of the Council, to open the discussion.

MR. BERTRAM BLOUNT, F.I.C.

Clinker.—Mr. Bertram Blount, in thanking Mr. Bamber for his paper, said that it was a very serious and solid contribution to a matter that was now of pressing importance to technical people. The notion current a few years ago, that there was some inherent difference between cement from a rotary kiln and cement from the old fixed kiln, had been exploded many times, and he was glad the *coup de grace* had been given by Mr. Bamber himself who once held a different opinion. He had now acknowledged the fact that, as a chemist, he was fully aware that the solid part of the clinker from a fixed kiln was precisely the same in composition and constitution—as far as they knew—except possibly for some small differences that were conditioned by the method of cooling, as the clinker from the other method of manufacture. And the composition was important in this regard, that the amount of lime that was a few years since supposed to be improperly high, was now accepted generally. The want of knowledge that the bulk of the well-burned clinker in the old days had the composition of modern cement, with 64 to 65 per cent. lime, arrived so slowly that specifications were drafted with most ridiculous restrictions, repugnant to the scientific knowledge of the time, and supported only by what Mr. Bamber termed the ancients.

Acid Bodies.—There was a most ingenious and useful suggestion where the notion was put forward that the adjustment of combination of aluminates and silicates in the cement may depend upon a number of conditions, influenced by the rate of cooling, and the maximum temperature reached, in such a way as to decide which of the two acid bodies would ultimately get hold of the lime. That theory was advanced a good many years ago in various articles, and, so far as we know, it had not been seriously combated.

Alumina.—It seemed to be reasonable that if a substance like alumina, which though in its fundamental properties was a base, acted at a temperature above the ordinary, it would become, as the temperature rose, more and more acidic, and tend to turn out the silica, which had an additional

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advantage, because it was acidic to begin with. Hence, it might be that the adjustment of the lime to these two acid radicles would vary according, not only to the temperature, but many other conditions. It was that sort of difficulty which had caused the troubles of the cement manufacturer making rotary clinker.

Hydration.—There was another matter again of great chemical interest. It was the fact that hydration occurred much more early, rapidly and completely, at a certain temperature. Mr. Bamber, by his ingenious method of putting steam through a tube mill, had discovered that the hydration proceeded more controllably, more systematically, and with a better ultimate result, when the average temperature was about 180 to 200° F., and that followed laboratory tests which showed that if it was desired to control the setting time of cement which was inconveniently quick, it was better done in the bath at about that temperature, even if the apparatus was stationary, and not a manufacturing affair at all. That, again, depended upon the plain chemical fact that most reactions proceeded more rapidly at a high temperature than at a low one.

Le Chatelier Tests.—He agreed with the author on the subject of the Le Chatelier test as now practised. A number of examples had been given of the difficulty experienced in condemning or passing cements on the Chatelier test as it stood. He had experienced no difficulty of that kind. Nevertheless, as it stood in its present form, which had not been varied one iota from the time of its illustrious author's inception of it, it was a satisfactory and a fair test, and a test that was accepted by users, engineers, and manufacturers alike; and until someone came forward and provided something better, he, for one, would adhere to it.

Setting Time.—The regulation of the setting time was important. It was a fact that manufacturers of rotary cement, preparing a cement that was really sound and good, had fallen into difficulties about the time of setting, and he thought the study of the means of control of setting time should be pursued.

MR. D. B. BUTLER, A.M.Inst.C.E., F.C.S.

Cement Formula.—Mr. Butler, referring to the formula for cement, said that he frequently had, in the course of practice, to manufacture cement on a small experimental scale to test its physical properties, and he found that Newbury's formula of tri-calcic silicate and di-calcic aluminate worked out very well in practice, and he invariably used it in his laboratory for working out a practical combination of the raw materials. Messrs. Day & Shepherd stated that fused calcium oxide hydrated or slaked very slowly, and went on to talk about the presence of free lime. Free lime in cement was practically an impossibility. He would prefer to call it an unstable lime compound.

Experiments.—Some years ago he followed out Newbury's experiments to a certain extent, and made several experiments to try and ascertain what was the real constitution of cement—*i.e.*, what the actual compounds were which made up the strength and properties of cement. One of his difficulties there was the lining of the furnace in which the pure silicate of lime and the pure aluminate of lime were used or burnt. Messrs. Newbury used some basic lining which, he thought, was partly compounded of cement clinker and some other things, but he found that that contaminated his pure alumina and pure silica, and gave him erroneous results.

Silica.—Mr. Butler believed that Mr. Bamber had made some mistake when he spoke of the constitution of pure cements. He (Mr. Bamber) mentioned that the amount of silica varied from 21 to 22·5, and the alumina between 5 and 6 per cent. Thus, taking the ratio of silica to alumina at 21 to 5, the result was between 4 or 5 to 1. He thought they would find that the ratio of silica to alumina, in most raw materials, was much nearer 3 to 1 or 2½ to 1.

Free Lime.—With reference to the point Mr. Bamber raised as to effect of the small absorption of water in his tube mill having a decided effect upon the action of gypsum, when added to it, Candlot said that such action was due to the presence of free lime. His own theory in that respect was this: the reason why gypsum did not affect freshly burned rotary kiln clinker, was that it contained no free lime, but immediately water was added to it, or it was steamed, one obtained a certain amount of action between the water and the cement, resulting in a CaO deposit or oxide of lime (crystals). That, on adding water, dissolved and set up the action described by Candlot.

MR. R. HARRY STANGER, A.Inst.C.E.

Le Chatelier Again.—Mr. Stanger thought that something more might be done about the Le Chatelier test. He had had experience of the extraordinary records of having the Le Chatelier test perfectly sound, and the Faija pats going to pieces. That was the severer test, showing the cement perfectly sound, whereas some lighter test proved it to be somewhat unsound.

DR. SIEGMUND ROSENFELD, Dr.Ph.

Aluminates.—Dr. Rosenfeld asked Mr. Bamber if he had prepared any mono-calcic aluminate, and whether he had investigated to what extent his aluminates contribute to the strength of the Portland cement? Two years ago he had an opportunity of hearing Dr. Schott expounding the setting of cement, and he mentioned then that the mono-calcic aluminate had a tensile strain in briquettes of

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over 700 lb. per sq. in. It would be interesting to hear whether Mr. Bamber made those same experiments, and whether he had obtained the same results.

Setting Time.—Mr. Bamber had mentioned that there were only two means of controlling the setting time; that was of storing the ground cement, and hydrating the cement. He (Dr. Rosenfeld) thought that if the clinker could be stored a certain time, that would give the means of controlling the setting time as well, and by storing the clinker all the troubles of changing the setting time, according to his experience, would disappear.

Gypsum.—Regarding the addition of gypsum, Mr. Bamber had said that by adding 2 per cent. of gypsum the cement showed a very great expansion. He found that even adding up to 4 or 5 per cent. of gypsum the cement remained perfectly sound, so long as the raw materials were properly prepared. Such expansion of cement was caused by the formation of the tri-calcic aluminate, sulpho-aluminate. That formation, according to Dr. Michaelis, happened only if there was tri-calcic aluminate present, and tri-calcic aluminate could only be formed if there was an excess of lime present. He contended that if the raw materials were properly prepared, and were reduced to a very fine state, they could add up to 4 or 5 per cent. of gypsum without showing any great expansion.

MR. W. LAWRENCE GADD, F.I.C.

A Correction.—Mr. Gadd said he had been quoted as suggesting a possible breakdown of small particles to account for the increase in the setting time of stored or aerated cement. He did not mean that that breakdown was brought about by the action of the air *per se*, but by the action of moisture. Mr. Bamber quite rightly threw doubt upon it, because he said it was difficult to see how the air could come into contact with those small particles when buried in the bulk of the cement, but it was not in his mind at all that the possible breakdown of particles was brought about by air, but by moisture, which moisture would be introduced either by steaming the cement in the mills as Mr. Bamber had described, or by the practice of wetting or moistening the clinker.

Setting Time.—It seemed to him—and he had a considerable amount of experimental data in support of the contention—that the setting time of cement was very largely influenced by the amount of combined water. Of course, it was perfectly well known that if cement was stored in a damp atmosphere it usually became slower setting. Other cements on aeration very often became quick setting, and he suggested the possible explanation of that would be that the cement became slow setting if it absorbed relatively a larger amount of water vapour, and quick setting if it absorbed relatively a larger amount of carbonic oxide.

MR. C. S. MEIK, M.Inst.C.E.

Setting Time.—Mr. Meik, in speaking of the setting time of the cement, said that, of course, in this new process there had always been a little difficulty about it. He believed that at one of the first meetings of the Institute, he made some remarks which were not very complimentary to that particular class of cement made in the rotary machine; but he was very glad to say that since that time his opinion had modified considerably. It was, no doubt, due to what Mr. Bamber had told them, in the manufacture of cement which came through the rotary machine, that he had succeeded in getting over a great deal of the difficulty, and they now obtained cement of which they have little cause to complain in regard to setting time.

Cold Water Test.—Mr. Meik said that Mr. Bamber's remarks about the expansion in cold water prior to the measurement being made in the Le Chatelier instrument all went to point out that they were wrong when they drew up the standard specification in eliminating the cold water test; that was plunging the cement into cold water immediately after it was gauged. Then the makers, in the old days, used to say that was the most severe test they could give, and, after all, in using cements in connection with under-water work, he would certainly ask for that test to be complied with in future, because it was rather disquieting to hear that cement occasionally did expand when it was put into cold water during the first 24 hours. That was a serious matter for concrete that had to be used under water, and which had to set within a few hours.

MR. GEORGE N. YOURDI.

Aeration.—Mr. Yourdi said that in spite of what he had heard with regard to gypsum, he was still a firm believer in aeration. He had used a considerable quantity of cement, both old and rotary kiln, and he found that with both kinds of cement he had had to aerate it, and not for 28 days, but for 6 months. He could not explain what the aeration did, but when he was in a fix, especially in the summer, he conceived the idea of filling the cement shed with hot steam, and in that way he succeeded in aerating cement in less than a fortnight.

The Chairman here announced that the meeting would be adjourned to permit of further discussion, and to hear Mr. Bamber's reply to the observations.

THE ADJOURNED MEETING.

Mr. BAMBER, Reader of the Paper.

Mr. F. E. Wentworth-Shields, M.Inst.C.E., presided, and opened the proceedings by calling upon Mr. Bamber.

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M. Le Chatelier's Letter.—Mr. Bamber said he had received a communication from M. Le Chatelier, who had been invited by the Institute to be present at the meeting, but who had been unavoidably prevented from making the journey from Paris. He read the following as a free translation of M. Le Chatelier's notes :—

NOTES OF M. LE CHATELIER (PARIS).

The notes are dated Paris, June 9th, 1909 :—

"The very interesting communication of Mr. Bamber raises many questions that I should like to discuss in order.

"***Tricalcic Silicate.***—The theoretical difficulties concerning the experiments of tricalcic silicate, have not the importance that is often given to them ; and, particularly, they have nothing to do with practical applications of cement. A confusion is often caused on this subject that it is important to get rid of. Although everybody admits that in a defined chemical combination combined bodies do not keep any of the properties that they have in a free state, there is a tendency to think that the same is not the case with solutions. That is an error ; solution and combination have exactly the same properties other than constancy of composition. *A priori*, there is no sort of reason to suppose that lime in solid solution in dicalcic silicate retains the property of slacking like free lime. In fact, the difference between solid solutions and combinations are so slight that often it is impossible to differentiate between them, even by the most exact laboratory experiments. From the very beginning of my researches into cement I have called attention to this double interpretation of the constitution of silicates of lime and given it to be understood that I did not lay stress upon it, because I thought it devoid of practical interest. In fact, at the present time, barring shades of expression, everybody is pretty well agreed upon the constitution of the active elements in cement. First of all there is a basic silicate, identical with tricalcic silicate, or nearly so, which can be obtained by burning, even when followed by a slow cooling. Secondly, there is a dicalcic silicate, which only keeps its hydraulic properties on condition that it is cooled suddenly starting from a high temperature; by slow cooling it tends to be transformed and to go to dust, and to lose its hydraulic properties. It is in consequence of this phenomenon that rotary kiln cement, which is always cooled quickly, is so superior to cement manufactured by the old process. Finally, there are different aluminates of lime. The phenomena connected with the hydration of these silicates and of these aluminates are also pretty well known to-day, at any rate, with regard to the formula of the resulting hydrated composition. The apparent divergence which is sometimes found between laboratory experiments upon these compounds, and the results obtained in manufacture on a large scale, are always due to the combination not being complete, owing to the want of fineness of the raw materials and the want of complete combustion. It is necessary to reduce the quantity of lime, which ought theoretically to correspond to the amounts of silica and alumina, because, in consequence of the incomplete reaction, part of this lime would remain free and would give rise to the phenomena of swelling and expansion that are so dangerous in the work.

"***Quickness of Setting.***—Mr. Bamber calls attention in his paper to a series of anomalies in relation to quickness of setting that are interesting. Mosts of the facts alluded to are inexplicable in the present state of our knowledge, and at first sight we might be inclined to deduce that our knowledge of the constitution of cement is much less advanced than the authors of works upon these questions pretend. It must not be forgotten that in the phenomena of crystallisation we are met by peculiarities quite independent of the fundamental laws of chemistry, relative to the proportions of bodies which are subject to reaction. The production of super-saturated solutions, the beginning of crystallisation, the form and dimensions of the crystals produced, vary in an absolutely capricious manner, or at least according to the laws which are extremely complex, and which are for the most part still quite unknown to us. Take at haphazard some peculiarities observed in laboratory experiments. Crystals of hypo-sulphite of soda developed by slow evaporation from their dissolution, such as those that are sold for photographic purposes, are equally developed according to all their dimensions ; but the same body crystallised in contact with a germ placed in a super-saturated solution presents itself in filaments, of which the length may exceed the diameter a thousand times. That is inexplicable. Or, again, if we introduce in a super-saturated solution of sulphate of soda a fragment of that salt recently melted it causes the crystallisation of the salt with 7 molecules of water, and not of salt with 10 molecules of water, which is the only stable one at the ordinary temperature. This, again, is inexplicable. Therefore there is nothing surprising in the fact that the setting of cement—that is to say, in the initial crystallisation of the hydrates produced—we should find anomalies of the same sort. The contrary would be surprising. In the present state of our chemical knowledge it would not be possible to foresee, *a priori*, the development of this or that peculiarity. We must content ourselves with observing them and accumulating concerning them the largest number of documents. From this point of view Mr. Bamber's paper constitutes a very important contribution to the development of our knowledge about the setting of cement.

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"The influence of sulphate of lime upon cement which has been previously hydrated, the swelling during the first period of hardening of cement to which gypsum has been added, are facts of very great importance which had not hitherto been mentioned.

"Hydration of Cement by Steam.—The process recommended by Mr. Bamber for slacking the free lime contained in the cement during grinding, by passing a jet of steam through the axes of the screw into the tube mills, is very interesting. I may be allowed to recall that in an article published 10 years ago in the *Bulletin de la Societe d'Encouragement*, entitled 'Slaking and Siloing of Lime and Cement,' I call attention to the advantage of slacking by steam at a high temperature. After this publication slacking by means of steam was commercially applied in the lime works of Teil where it is still in current use.

"Tests of Unchangeability of Volume in Heat.—Mr. Bamber makes two objections to the test for stability of volume which bears my name. He considers it first of all too severe for estimating the free lime, because it reveals proportions of lime too insignificant to be really harmful in practice. I agree with Mr. Bamber on this point; but experience has shown that all manufactories working scientifically have not had much difficulty in satisfying this test. Therefore, there is no harm since it is possible, in giving the consumer a somewhat excessive guarantee.

"Mr. Bamber mentions in reference to this test a very important fact, to which attention had not hitherto been given. In cement to which sulphate of lime has been added a considerable swelling is sometimes produced during the setting, even before there is any action of heat. This fact was not known. It certainly would be interesting to make, while cold, a first measurement of the swelling before immersion in hot water; but, perhaps, for measuring this initial swelling it might be better to employ a different process than that of split-needle moulds.

"The expansion developed during swelling occasioned by sulphate of lime is always very small, infinitely smaller than during the slacking of lime. The resistance of the metallic mould reduced it considerably. No doubt better results would be obtained by the process which I formerly recommended for steadying the expansive action attained by the addition of sulphate of lime already hydrated. This process consisted in gauging the cement with a very small quantity of water, about 15 per cent.; this necessitates rather energetic pressure for making the briquettes, but on the other hand allows of their being taken out of the mould immediately, so that afterwards they can swell freely, because they are not shut up within any resisting walls. Two very fine streaks traced upon one of the faces of the mould gives upon the briquette small ridges, the changes of distance of which can be measured by an optical process. In this way variations of length can be estimated which do not reach one-thousandth part of the first dimensions."

MR. BAMBER, F.I.C., Reader of Paper (*continued*).

Continuing, and in reply, Mr. Bamber regretted M. Le Chatelier's absence, but in expressing his gratification for the trouble he had taken, he thought he was voicing the opinion of all present when he said that they were all much indebted to M. Le Chatelier—who was a most eminent authority on such matters—for his very interesting and instructive communication. They would remember that in his opening remarks he purposely disclaimed any intention, or, indeed, capability, to expound any new theories, confining himself to the practical side of the question, and he was pleased to accept the very comforting assurance of M. Le Chatelier, that the many theoretical difficulties of the supposed complex chemical combinations that might be formed had not the importance that was usually attributed to them, and, further, that they had nothing to do with the practical application of cement. With that information he thought the manufacturer might well leave those questions to the specialists who had nothing else to do, and the consumer of the cement need not worry himself on the score of the chemical side of the question, but confine himself to seeing that the cement he purchased complied with the practical clauses of his specification.

Formation of Silicates.—In describing the formation of the various silicates and aluminates present in cement and their action under varying conditions, it was interesting and particularly gratifying to him, and, no doubt, to many others, to have such a definite statement from such an eminent authority as Monsieur Le Chatelier as to the superiority of rotary kiln cement over that manufactured by the older processes. He mentioned some most interesting facts with regard to crystallisation, which showed how the formation of crystals was materially changed by the most trifling alteration in the prevailing conditions under which the crystals took place, and in view of those very interesting facts held that it was not surprising that some of the anomalies of the set of cement that he had referred o were inexplicable, such, for instance, as the influence of 1 per cent. or less of combined water in the setting time of the whole mass.

Slaking of Lime.—Monsieur Le Chatelier referred to his experience in the slaking of lime with steam at high temperature, confirming his experience in the hydration of cement. The difficulty, however, was to apply such a system to cement without causing damage to the material itself, and it was not until the process of applying the steam through the axis of the conveyor screws into the tube-mill was introduced that that was successfully accomplished.

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The Le Chatelier Tests.—With regard to Monsieur Le Chatelier's remarks as to his objections to the test which bore his name, he was mistaken in supposing that he attributed the points of his objection to the presence of insignificant proportions of free lime. That certainly could not be the case, because he had shown that cement made with a clinker of an absolutely uniform composition the fine portion of the powder constituting the greater quantity of the cement was in itself perfectly sound, but when tested in conjunction with the coarser particles expansion on boiling taking place, which was removed if the coarser particles were first also reduced to a fine powder. Now it could not be supposed that the residue referred to had appropriated to itself a greater proportion of lime than the remainder of the cement, and even if that were so, the mere reduction to a fine powder would not remove the expansive effect of an excess of lime if it were present, whereas the said reduction removed altogether the expansion referred to. Thus the causes of such expansion must be sought for in other directions.

Test Difficulties.—He agreed with M. Le Chatelier that with modern well-conducted works the test did not offer any very great practical difficulties; in fact, so little that it was common, more especially with rotary cement, to find that the expansion when freshly made and hydrated was frequently only 10 per cent. of the permissible minimum of the British Standard Specification of 10 millimetres—namely, only 1 millimetre. The suggestions of M. Le Chatelier for measuring the expansion in cold water of cement containing an excess of gypsum were most interesting and should have their careful consideration.

MR. WALTER F. REID, F.I.C.

Lime and Cement.—Mr. Reid said, with regard to Mr. Le Chatelier's observation as to the lime being present in cement in a different form from that in which they were accustomed to see lime, and in which it slaked and expanded very considerably in volume, he thought that was a remark of very great importance. In many cases, as in slags and metallurgical products, they knew free lime was there, and yet when the product was put in water it neither slaked nor expanded, although the water into which it was put became alkaline, and took up lime. He opined that there could be no doubt whatever that at the temperature at which Portland cement was clinkered the lime did exist in a different state to that in which it existed in the ordinary burned lime, and that, he thought, was one of the reasons why the surcharge of free lime had given so much trouble to different investigators.

Retarding Action of Fuel Ash.—With regard to the retarding action of the fuel ash on the setting of the cement he believed Mr. Bamber had rather exaggerated the point He confessed to being one of what Mr. Bamber called "the ancients." He had made many thousands of tons of cement in the old way, in the old kilns, but his experience showed that the ash had very little to do with the setting of the whole charge of the kiln. Many times he had picked out pieces of clinker from a kiln and ground them separately, and found they had more or less agreed with the setting of the bulk of the charge from the same kiln. He could not see how it could be otherwise, because the ash, on Mr. Bamber's own figures, was a very small proportion of the total charge of the kiln, and that ash only came into contact with the outer surfaces of very large fragments of the raw mixture. Those familiar with the burning of cement know that the lumps of dry slurry that had been put into an old-fashioned kiln sometimes came out practically in the same form as they went in. Consequently, to him it was quite impossible that the small percentage of ash which was contained in the fuel could have any appreciable difference in the time of setting of the cement; and he stated definitely, as the result of his experience, that the time of setting was dependent upon the composition of the material as it was put into the kiln, and only in a very small degree indeed upon the small fraction of ash that might be derived from the fuel.

Sulphur Compounds.—Regarding sulphur compounds, he criticised the view which was expressed by Mr. Bamber that the sulphur went away in the gases in the rotary kiln or any other kiln. They knew from other chemical manufactures that where gases were passed containing sulphur through a medium in which lime prevailed to a very considerable extent that it combined with the lime. If the contents of the kiln were acid, instead of being basic, as they were, then the idea was probable, but if gases containing sulphur escape it could only be a proportion of the sulphur, and that a small one.

Carbonic Anhydride Action.—With reference to the action of carbonic anhydride, Mr. Bamber originally stated that the CO_2 acted on the cement. That was an error. Carbonic anhydride did not act on the cement at all. It could only be when it was combined with water that it would act. He had tried the experiment, and found that carbonic anhydride did not act even on caustic lime. Carbonic anhydride required water before it would act.

Swelling of the Gypsum.—With regard to the interesting letter of M. Le Chatelier, he referred to the swelling of the gypsum. There was no doubt that gypsum in certain forms did not take up water readily. They had very large masses of the mineral called anhydride which was the sulphate of lime in the anhydrous condition, and they had hundreds and hundreds of feet depth of that which had not become hydrated in the course of very long periods of time, perhaps millions of years. They

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did not know how long, but by degrees, when the superficial layers did become hydrated, there was enormous swelling and great contortion of the strata, and it was one of the difficulties of boring for salt in Germany and other places, where those anhydrite forms existed, that the contortion of the strata was so great that one really did not know in what position you would find the next layer when it was bored through. Therefore, they might assume that gypsum in certain forms—and it is quite possible that these forms might exist in cement—if they add it to the cement in the first instance and burn with it, might be present in a form that took up water so slowly, that within the limits of the time devoted to such experiments, it appeared to be absolutely inert.

Setting Time.—With regard to reducing the time of setting or lengthening it, some very interesting experiments were made a great number of years ago on a large scale in Germany. He believed there, in the ring-kiln, they used at that time (it was very many years ago) to sprinkle water on the clinker before it was cold. The cement, they found, set more slowly, and altogether it was considered a considerable commercial advantage, and at that time it was kept secret; but, oddly enough, he had previously used it in cases where the stone was not so intimately mixed as it might be, and there was almost visible free lime in some of the clinker. In those cases an addition of moisture to the hot clinker improved the cement without materially diminishing the strength. That very ingenious process which had now been devised by Mr. Bamber for carrying out the partial hydration in a measured way was likely to get over any difficulty that still remained in that particular operation.

Mr. W. GILBERT, M.Inst.C.E.

Controlling Setting Time.—The methods adopted by many manufacturers at the present time to control the rate of setting was as follows: (1) To sprinkle the clinker, leaving the clinker coolers, with a definite quantity of water, generally from 1 to 2 per cent, and (2) to add gypsum, or plaster of Paris, previous to, or during the process of grinding in the ball and tube mills.

The final temperature of the cement as it left the tube-mill, due to the work done on it in grinding, was from 140° to 150° F., so that in ordinary practice the gypsum and water and cement were incorporated together at a somewhat lower temperature than that. By using steam instead of water, Mr. Bamber raised the temperature to nearly 200° F., or an addition of 50° F. The addition of the moisture was also no doubt better controlled.

Temperature. —Mr. Gilbert said that it was stated that the cement passed the Le Chatelier test better if the temperature was kept above 180° F., and he would like to ask if the setting time was also better controlled by preserving the higher temperature of 180° F., as against 140° F., which was more usual. Mr. Bamber did not say how, or where, the gypsum was added in regulated quantity; that was rather an important point. With reference to the Le Chatelier test, the attitude of Mr. Bamber and Mr. Butler appeared to be reasonable.

The Faija Test.—The evidence seemed conclusive that the Faija test, which subjected the test pats to a temperature of 120° F., was sufficiently severe to reject all unsound cements, and he would like to know what were the defects of a cement which the Le Chatelier test would discover, and which the Faija test would not discover? On the other hand, the Le Chatelier test was an ingenious quantitative test, but it did appear to be a weak point that no measurement of expansion was commenced until the cement had been immersed in water for 24 hours, if, as Mr. Bamber stated, considerable expansion occurred sometimes during that preliminary period.

Expansion.—It would be found by calculation that the maximum expansion of 10 mm. under the Le Chatelier test, permitted by the British Standard Specification, corresponded to an increase in volume of the cement of 2 per cent. Nothing like that could occur when such a cement was used in practice, even if used neat, and it was thus open to doubt as to whether the expansion of the cement when actually used in any way followed on a reduced scale, the indication of the Le Chatelier needles, under the influence of the boiling test.

MR. A. O. TRECHMANN, F.C.S.

The Rotary Kiln.—Mr. Trechmann agreed that the rotary kiln was rapidly developing, but he did not think it had established a firm footing in this country yet. He did not think that Mr. Bamber had established a case against the fixed one. He had referred to the clinker from the rotary kiln as being comparatively homogeneous, containing practically no free lime in the amorphous condition, and being entirely free from contamination of the fuel. He believed a certain proportion of the fuel ash did escape from the kiln, but some was doubtless retained, especially where the incoming raw materials were in a wet condition.

Quality of the Fuel.—As to the quantity of the fuel used in the intermittent processes, he would like to remind Mr. Bamber that some types of fixed kilns consumed more than 33 per cent. less than the best handled rotary kilns which operated on the wet process. He referred to the fuel which came into contact with the cement. The coke used, moreover, was not so impure as Mr. Bamber put it. He (Mr. Bamber) said from 12 to 15 per cent. out of 228 analyses. He (Mr. Trechmann) obtained an average of 11·06 per cent. of ash, the coke being derived from about seven sources.

Le Chatelier's Test.—He expressed no opinion on the value of the Le Chatelier test beyond mentioning that he had found it useful; but Mr. Bamber's observations in that connection of the behaviour

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in cold water of cements containing added gypsum were worthy of further careful investigation, and he hoped they would soon have an opportunity of listening to another paper by Mr. Bamber on that subject, which would, he was sure, be greatly appreciated.

MR. G. B. BLYTH.

Lime Percentage.—Mr. Blyth said it was a common occurrence in Warwickshire to get picked clinker that only showed 60 to 61 and perhaps down to 59 per cent. of lime, and some of those present that evening would agree that the cement made from that clinker, outside one particular point, was as good as most people's.

Setting Time.—As to the alteration of setting time, he was speaking more of a cement made from the limestone, than chalk and clay. They used to manufacture, and they did sometimes now, a very slow-setting cement—that was, a cement that took four or five hours to get its final set. But, speaking of the last two years, he had sometimes made a cement that, although it took, say, 250, 280, or 300 minutes to set the same day it was ground, or early next morning, become very quick setting a day or two after. He had made a number of experiments, extending over a period of five weeks. He started with 280 final. Somewhere about the first fortnight he got as quick as 7, and finished his five weeks down to about 35. He believed that if he had gone on it would have got slower still.

Meteorological Conditions.—There was one important point he noticed in carrying out his experiments. He kept a record of the fall of his barometer as to the weather. It often fell during the test period, and whenever it fell it was always a wet day, and whenever it was quicker setting the chart showed a dry day. That was one of the points that he tried to make—that in the cement of to-day, they were confronted for some reason or other with different results, from what they had experienced in what he might call the good old coarse-ground days. That was due, he believed, to fine grinding, especially of the raw material and that had made some peculiar differences to the setting time of cement which were not shown by chemical analysis.

Ash.—Mr. Bamber had referred to the ash retained in the old intermittent kiln, and the ash that he believed went up the chimney in the modern rotary kiln. Now, Mr. Blount had described it as rubbish, and he quite agreed with him that it was a very good rubbish. In the modern improved forced draught or induced draught Schneider kiln less fuel was used than in the rotary kiln, but what little was used would permit of conserving the ash as much as possible. Perhaps they would not quite appreciate that, but ash, if it went up the chimney, was worth nothing; ash which could be sold quâ-cement was a valuable product. There was no doubt it did improve the cement, and it was much better to keep that ash in the clinker.

Le Chatelier's Test.—Proceeding, Mr. Blyth said he was strongly opposed to this test. He had complied with the Le Chatelier test, but he found it most misleading.

MR. J. F. PLAISTER.

Lime Limit.—Mr. Plaister referred to the limit of lime which Mr. Bamber had mentioned in his paper, which really first-class cement must contain. He said it should contain 63·5 to 65 per cent. of lime. That must be wrong, for he had had passed through his hands plenty of absolutely the highest grade cement made by the rotary kiln process, with as high as 67 per cent., and as low as 58 per cent., and he was sure that the quality of that cement was equal in every respect to those cements containing lime within the limits Mr. Bamber spoke of. It entirely depended on the material with which the cement was made; and there he would say that the method of regulating the setting time was different, too. Mr. Bamber attached no importance to the gradual cooling of rotary clinker as regards setting time. He could not agree with him.

Aerating Cement.—He would like to warn those engineers who were so attached to the old method of aerating the cement after they had received it of the danger they ran in doing this, of destroying part of the virtue of the modern finely ground cement, rendering it to a great extent inert, more especially if the cement had been made from clinker which had been thoroughly aerated before grinding. It had been absolutely appalling to him to see cement put into the most important work which had been ruined by the suicidal mania for over-aeration.

Dr. Rosenfeld had referred at the last meeting to the addition of 4 or 5 per cent. of gypsum as being safe. Perhaps it was, but he would say it was verging on the edge of danger, and it was best left alone.

Temperatures.—He was sorry so little was said in Mr. Bamber's paper as to the importance of temperatures when making tests for setting time. Limits were laid down in the British Standard Specification as to the temperature the air and water should be kept where the tests are being carried out, but he had not yet come across any testing-room where proper provision was made to keep the temperature within these limits during every state of the weather. He had often gone into what was supposed to be a properly and well-equipped testing-room, and he had found that the temperature had been falling below freezing point during the night, and getting to up goodness knows what during the day. Could not something be done to pay some little attention to regulating the temperatures in the testing-rooms in which tests were carried out?

MR. J. W. DAVIS.

Intermittent Kiln Clinker.—Mr. Davis observed that probably some of the differences which manufacturers found were due to the different materials with which they worked. His experience had

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been with cement made from chalk and clay, and with both intermittent kilns and with rotary kilns Since Mr. Bamber read his paper he had made some experiments with intermittent kiln clinker on the lines suggested in that paper, and he had found that when well burned intermittent kiln clinker was, as Mr. Bamber had said, almost of instantaneous set ; in fact, he found the initial set of clinker of that description was equally as quick as cement from rotary kilns. He had yet to learn that any one had found that they could produce cement from rotary kilns made from chalk and clay that was anything but quick setting when first ground, unless it was treated by some method for retarding the initial setting time.

Setting Time.—He believed that Mr. Bamber's observations on the setting time were very valuable. He thought they owed a debt of gratitude to him for showing how cement could be slowed in its setting by the addition of moisture in the shape of steam, with a very small percentage of gypsum. Until the results of Mr. Bamber's experiments were proved to be incorrect it must be held that Mr. Bamber had given an exceedingly valuable contribution to the question of the retarding of the setting time of any sort of cement.

MR. G. J. FENWICK, A.R.C.S.

Hydration Effects.—Mr. Fenwick pointed out that Mr. Bamber did not say what effect his hydration had on the hardening of the cement. There was some rotary kiln cement in which, although it appeared to take an initial set in a reasonable time, the hardening was sometimes delayed considerably. He did not know if Mr. Bamber's process had any similar effect. It seemed to him that when the steam got at the cement in the tube mill it was merely the same as what happened in other experiments that had been tried with the idea of hydrating the cement otherwise than in the tube mill. When this was tried in other cases, even at the same temperature, lumps formed, and it seemed to him the great virtue of Mr. Bamber's method was that all those lumps were broken up, and the consumer did not see them at all. Consequently, he did not know whether there was any damaged cement there or not.

Colloid Theory.—Another point he wished to make was that he noticed Mr. Bamber spoke about the Michaelis colloid theory, and it seemed to him that that explained a great many of the peculiarities of the set, because the 1 per cent. of water destroyed 10 per cent. of the cement, which must be all on the outside of each particle of cement, and those particles, being all coated with collodial matter, would not be readily affected by water. Moreover, they would not have any effect on the gypsum.

THE READER OF THE PAPER REPLIES.

Mr. Bamber, in reply, said it was impossible for him to deal with the enormous number of points that had been raised. He would reply to the discussion which took place on the last occasion. He would add, however, that when he read his paper he endeavoured to make it clear that he was seeking rather than giving information, and he had learned much during the discussion.

Percentage of Lime.—In reply to Mr. Blount, he was pleased to find him so much in accord with the views he had generally put forward. With reference to Mr. Blount's remark, in which he said he was slow in coming to the opinion which he had for some few years been expressing as to the relative percentage of lime in ordinary and rotary cement, that might be true, but it must not be forgotten that the cement manufacturer on a large scale had not that license to make mistakes which was well known might be enjoyed with impunity by the scientific expert. If a cement manufacturer made a slip, the brunt of it fell upon his own shoulders, and it behoved him to step cautiously ; the scientific expert, however, had no such heavy burden to bear should his opinions be found to have been somewhat exaggerated.

Suitable Rubbish. — Mr. Blount had alluded to the retarding action of the fuel rubbish found in old process cements, and suggested that the time had arrived for the expert to find a suitable rubbish to mix with the sound and good clinker from the rotary kilns. That was a very wide subject. For many years suggestions had been made that Portland cement would be improved by the addition of puzzolana burnt clay or some such silicious material, and that idea was put into commercial practice some years ago in the cement trade, but had since been discontinued. There might be some beneficial results obtained by such process, but at the present time he thought that the engineer was better advised in seeing that he obtained a pure Portland cement, and took particular care to see that he produced with it, by a proper and scientific grading of aggregates, a concrete of impervious character, when many of the difficulties which have been referred to in that connection would disappear. Mr. Blount had described him as a " past-master in rubbish "—truly, he was, from his experience gained in the use of breeze concrete and slag cement. Mr. Blount qualified that remark by saying that he meant it in the chemical sense. He would therefore give them the chemical reason for describing breeze as rubbish in connection with building construction. No doubt there were many present who had had disastrous experiences with breeze concrete. In his opinion the chief cause of failure was almost entirely due to the presence in the breeze of unstable oxidisable sulphur compounds. The origin of such rubbish was simple. It existed primarily in the coal as iron pyrites, ferric disulphide (FeS_2), in which condition it was practically a stable compound. During the distillation of the coal in retorts

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or its combustion in furnaces that substance was not always completely oxidised, and there remained in the breeze or ashes an amount of ferrous sulphide (FeS), one atom of sulphur having been evolved. That, like calcium sulphide in slag cement, was unstable and easily oxidisable. When used for concrete purposes the ferrous sulphide in the breeze in contact with air and moisture became oxidised and converted into ferrous sulphate ($FeSO_4$), which, reacting on the alumina present in the cement, produced the formation of sulpho-aluminate of lime, combining with 30 molecules of water, causing very considerable expansion. In the case of the slag cement they had a very similar condition of things—sulphur compounds of an unstable character derived from the fuel and materials used in the blast furnace—often amounting to as much as 6 per cent. of calcium sulphide with traces of ferrous sulphide. When water was added to such cement its unstable character, liable to the actions described in the case of breeze, was indicated by the evolution of sulphuretted hydrogen which was easily detected. He thought anyone who had had any experience with such unstable compounds for building construction might well claim to be a past-master in rubbish, and he thanked Mr. Blount for the distinction he had conferred upon him.

The "Le Chatelier" Test.—He entirely agreed with Mr. Blount in his eulogies of the "Le Chatelier" test. It had probably done more to improve the quality of Portland cement than any test at present in use. There were the anomalies, however, which he had mentioned, and which were well worthy of his consideration, more especially as he frequently had to pass an impartial judgment on cements subjected to that test. With reference to Mr. Blount's inquiry as to the method of conducting the tests of solubility of gypsum, he might say that materials were ground to the same fineness as they would be found in the cement, they were violently agitated with distilled water at 62° F., and the liquid thrown upon a rapid filter, the quantity of solution passing through being collected up to the completion of the time indicated by each test.

Formulæ. — He agreed with Mr. Butler that the subject matter of the constitution of Portland cement might well be taken up by the National Physical Laboratory and thoroughly investigated. Mr. Butler said that he frequently used the Newbury formula of tricalcic silicate and dicalcic aluminate in the manufacture of cement in an experimental way, and no doubt that method of calculation was in the main correct, as he had pointed out that the percentage of lime necessary to form a good cement was nearly equal to that required to form the supposed tricalcic silicate, although the actual constitution might be the dicalcic silicate in a solid solution of lime.

Furnace Lining.—Mr. Butler had asked him as to the lining used in the furnace employed in his experiments in the formation of silicate and aluminates of lime. He would point out that he had not described or made any experiments on the silicates of lime, his work being confined to the aluminates. In all cases his furnaces were lined with material of the same composition as that being operated upon.

Ratios.—Mr. Butler alluded to the ratios of silica and alumina that he had mentioned, thinking that that was put somewhat too high. As a matter of fact, the ratio worked out on average about 3¾ to 1. That ratio depended, of course, entirely upon the composition of the raw materials, but a cement with a ratio of 2½ silica to 1 alumina mentioned by Mr. Butler would, he believed, produce a very quick-setting cement, difficult to manipulate, and having a high content of alumina, which was thought by many would be objectionable, especially in connection with sea-water work.

Atmospheric Conditions.—Mr. Stanger, who was fully conversant with the effect of temperature and other atmospheric conditions on the setting time of cement, agreed with the suggestion that the manufacturer should have the fullest particulars of what was required. That was true; it was one of the unavoidable difficulties of the cement manufacturer. He thought, however, those changes due to temperature were not in effect so serious as Mr. Stanger imagined, as they applied more to the samples that were operated upon for testing purposes than to the bulk in store.

Expansion after Aeration.—Mr. Stanger had referred to the fact that he had occasionally come across cement which showed an increased expansion after aeration. When such an experience was obtained he thought it was chiefly caused by some disorganisation of the setting functions by the long exposure, which theory was borne out by the fact that if a somewhat longer period was allowed after gauging before boiling the cement the apparent increased expansion entirely disappeared. He had in the past conducted many experiments and had many communications with M. Le Chatelier on that point, but, seeing the cement was as sound as formerly if only given a few hours longer in cold water before boiling, he was only able to come to the conclusion already expressed.

Setting Time Trouble.—Dr. Rosenfeld had suggested that with a proper storage of unground clinker all troubles or changes of setting time would disappear. He did not think that that was borne out by one's experience in countries where such custom was adopted. Take Germany, for instance, with which Dr. Rosenfeld was well acquainted. That was a common custom, and yet one had been interested in reading the papers that had been discussed from time to time at the Berlin Annual Meeting of Cement Manufacturers on proposed methods of preventing the change of setting time of cement when in store or in transit. It was his opinion that the hydration process, which had worked so successfully in England, when applied in Germany, would remove all the major difficulties.

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Constitution of Cements.—Mr. Reid had referred to the question of the constitution of cements and the lime being in solid solution. He agreed with him. That was a theory which had only recently been propounded, and he believed it was a theory which was practically confirmed, that in all probability the condition of the lime in a crystaline, as compared to the amorphous state, was the reason why experts were unable to find free lime in that cement, because it did not act in the same way as did the amorphous quicklime.

Clinker. — Mr. Reid further pointed out in regard to clinker obtained from an ordinary kiln that one could, when drawing the clinker, in many instances see pieces of clinker the shape of the actual pieces of slurry with the tool marks on it before it was placed in the kiln. He did not know whether he quite realised, as he did, that that was the very sort of clinker which he referred to from time to time when he spoke of the clinker which was obtained from an ordinary kiln which was not contaminated in any way by the ash from the fuel. That piece of clinker which he referred to was no doubt a piece of clinker which was not in actual contact with the fuel, but was burned by the radiating heat from the fuel which was close to it, and it passed through the kiln perfectly calcined, but not contaminated in any way by any of the ash from the kiln. That piece of clinker, if he had examined it, he would have found, contained no less than 64 per cent. of lime.

Ash and Setting Time.—Mr. Reid dealt at some length with the ash as having effect upon the setting time of cement. If they would refer to his remarks they would see that he did not state that it had to any very great extent, but he put it forward as a possibility that it might have some effect in retarding to a very slight degree the setting time of the cement when untreated ; but it most certainly had a very considerable effect in the alteration of the chemical composition on analysis of the ground cement, because whether cement was burned in an ordinary kiln with coke, even if it contained as little ash as Mr. Trechmann said it did, about 11 per cent., even with that coke and with a raw material which had been carefully prepared, which if calcined in the absence of fuel would show 64 to 65 per cent. of lime, he was quite certain that if the cement or the clinker, including the hard pieces and dust from Mr. Trechmann's kiln, were mixed up, it would not have contained on an average on analyses more than 62 per cent. of lime at the most. It was fair to assume that as nothing else had been put into that kiln but coke and the ash that was in it, that it must be that ash which had accumulated on the clinker to such an extent as to cause the percentage quantity of lime to be reduced from what it should have been, 64 to 65, to about 62.

Carbonic Hydrate Action.—Mr. Reid then also referred to some of the experiments described, and in which he alluded to the action of carbonic anhydride upon the calcined aluminates, and he (Mr. Reid) questioned the results of those tests by stating that the action of CO_2 on the aluminate could not possibly take place, except in the presence of moisture. Mr. Reid would not have said that if he had read the paper a little more carefully, and had realised what were the experiments that he was trying to describe. The cement which was submitted to the carbonic anhydride were the pats of cement which had been gauged up with water, and which were wet, and which were submitted to CO_2 within a very short time after they had been gauged, therefore the water which Mr. Reid said should have been present in order that the action might take place was there in the cement, in abundance, more than was required for the action. He thought Mr. Reid must have misunderstood his remarks, and supposed that they were submitting the dry cement to dry carbonic acid.

Silicates. — He also referred to the results to be obtained with silicates. He would point out to him, as to Dr. Rosenfeld, that he did not make any experiments with silicates, nor did he report on their action. He then touched on the question of carbonate of lime, and argued that it was not an inert substance. That was one of the new things that he had learnt from the discussion.

Temperature and Setting Time.—Mr. Gilbert had asked whether the setting time of the cement was appreciably improved by keeping the temperature of the tube mill at the temperature mentioned, about 200° as compared with 140°. He would say that the effect of doing that sort of thing, as, in fact, was the effect when one attempted to bring about any chemical combination of that kind, was always greater, and more rapid, if one could do it at a high temperature—and in connection with that he would say that it was found most beneficial to the cement that the temperature should be kept high, because it enabled one to produce a cement straight from the tube mill without aeration of any kind or sort after it had left the mill—it enabled one in that way to produce a cement which, when tested by the Le Chatelier test, did not expand even the 10 millimeteres, which was the minimum in the British Standard Specification, but it was common to get cement tested within an hour of its leaving the mill after hydration expanding only 1 millimetre in the Le Chatelier test.

Expansion of Cement.—Mr. Trechmann had said that in raising the question of the expansion of cement in cold water one was raising, not a bogey, but a question which was liable to make the consumer of cement nervous. He was sure Mr. Trechmann would give him sufficient credit for common sense not to raise a question of that sort without sufficient cause. But surely the time had come, when one heard the consumer asking some very nasty and ugly questions about it, that somebody should step into the gap and try to give the proper scientific explanation before the customer lost faith in the cement he was using. He thought, therefore, he could claim, not to have raised a question which

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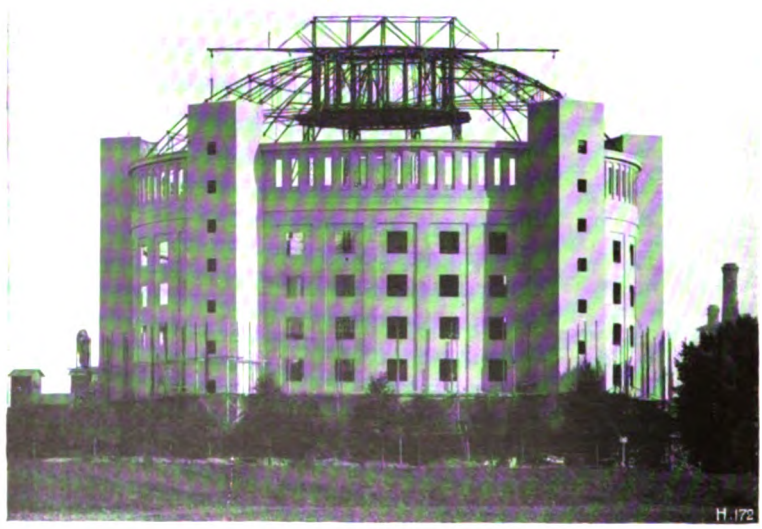
would disturb the customer, but he hoped the result of their deliberations would prevent the consumer having any failures as the result of any such action in his cement. He was sure that any engineer who had listened to the discussion would realise that at least the cement trade in this country was conducting its business on a thoroughly scientific and a commercial basis, and that questions of that sort might be very well and safely left in their hands. Mr. Trechmann dragged him into commercial questions which he attempted to avoid. But he said that the rotary cement, or the rotary kiln, had not yet found a footing in England. He did not think he was overstating the case when he said that nearly half the cement used in this country was manufactured by the rotary process to-day, and that the prospect of the half which was manufactured on the older system being reduced was, he thought, very near at hand. While on that subject he would answer a question which was put by Mr. Blyth. He again dragged in the commercial question, which forced him to make a commercial reply. As to the plant which he referred to, he seemed to be supposing that because they were putting up other kilns which were not rotary kilns they were going practically to pull down the rotaries. The rotary kiln was a splendid thing if there were a pack of them; it was not worth much commercially if worked as a single kiln unit.

Eliminating Ash. — Mr. Trechmann had said, and he was very much struck with the remark, that the ash from the fuel could be eliminated from the clinker by a very simple process. As a cement maker he had never yet heard of any method whereby the ash of the coke which had intermingled with the clinker and the dust which was drawn from the kiln could be separated before it went into the mill from the clinker, at least, no commercially practical method.

Working of the Rotary Kiln.—Mr. Blyth's reference to the working of the rotary kiln also afforded him a very great deal of information and some amusement. He discussed at some length the question whether the ash was retained in the kiln or not, wholly or in part. But he would refer him to his paper in which he would see that he did not say that the whole of the ash was eliminated through the chimney, but a very large proportion of it was. He knew that a certain quantity of it must necessarily be retained when the gases containing these dust particles were passing through the wet slurry at the top end of the kiln, but he did not agree with Mr. Blyth when he said it was better for the customer to have cement with ash in than to have cement without it.

Conclusion. — As the Chairman was anxious to close the meeting, with his consent he would add a few other remarks in the form of correspondence. He believed there were several letters written by gentlemen who were unable to be present. If he was permitted he would add a few words in reply to any questions which he had not already answered when he came to reply to the correspondence, and both would appear in the proceedings of the Concrete Institute.

The Chairman then announced that he had received various written communications that would be printed in the Transactions of the Institute, and that the meeting terminated.



A Reinforced Concrete Gasholder near Dresden.
Fig. 4. Structure nearing completion.

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FIG. 6. REINFORCED GASHOLDER NEAR DRESDEN.

REINFORCED CONCRETE GASHOLDER near DRESDEN

(Free Translation from the German).

We present a further continental example of the a plication of reinforced concrete to industrial purposes and we are in this case indebted to Messrs. Dyckerhoff & Widmann, of Dresden, for the photographs, as also to "Armierter Beton," in which some similar illustrations and the description have previously appeared.—ED.

IT is now becoming the practice on the Continent to enclose gasholders in an external building, in order to protect the bell and guides against the weather. Since, moreover, the cost per unit of volume diminishes with the size of the gasholder, there is a considerable advantage in constructing one large holder in place of several of smaller size. When brickwork is used, however, the load on the foundation becomes very heavy in the larger structures, necessitating costly foundation work. A great saving may be effected by the employment of reinforced concrete, the saving in weight as compared with brickwork being about 30 per cent., the reduction in thickness of the wall about 50 per cent.

A large gasholder has been recently constructed for the municipal gas works at Reick, Dresden, and has a capacity of 110,000 cub. metres (3,300,000 c. ft.). The structure consists of three parts, a ring-shaped container, and an enclosing wall, both of reinforced concrete, and a steel frame domed roof and lantern.

The ring-shaped container is constructed for a depth of water of 10 m. (32 ft. 10 in.), and also serves as the foundation of the enclosing wall. The method of construction is seen in *Fig.* 5. A double layer of asphalted felt was first laid, followed by the reinforced concrete slab, 1 m. (3 ft. 3 in.) thick. The thickness of the container wall at the upper part was only 60 cm. (2 ft.). As the wall was raised, the back was tarred, the inner surface being finished with fine cement mortar. The timbering shown was again used in building the superstructure.

Figs. 2 and 3 show the enclosing wall in course of construction. It was necessary to provide for great stiffness in the scaffolding and timbering, in order to resist wind-pressure. Stays and cables were used to anchor the scaffolding securely to the ground. To ensure an exactly circular form, the centering was checked by wires from a central tower, a revolving skeleton wheel, pivoted in the centre, being used for testing the exactness of the shape.

The enclosure wall consists of a plinth, 7·6 m. (24 ft. 11 in.) high, and 75 cm. (2 ft. 5 in.) thick, then of the main wall, 23·85 m. (78 ft. 2 in.) high, the panels being only 20 cm. (8 in.) thick, and the upper ring and cornice, 9·25 m. (30 ft. 4 in.) high.

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The five towers with internal staircases, seen in *Fig.* 4, are added chiefly for architectural reasons, to break up the surface, and do not contribute in any important degree to the stability of the structure. They are not rigidly connected with the wall, as such a construction might easily cause cracking during changes of temperature. They were, in fact, erected after and independently of the wall. Five horizontal

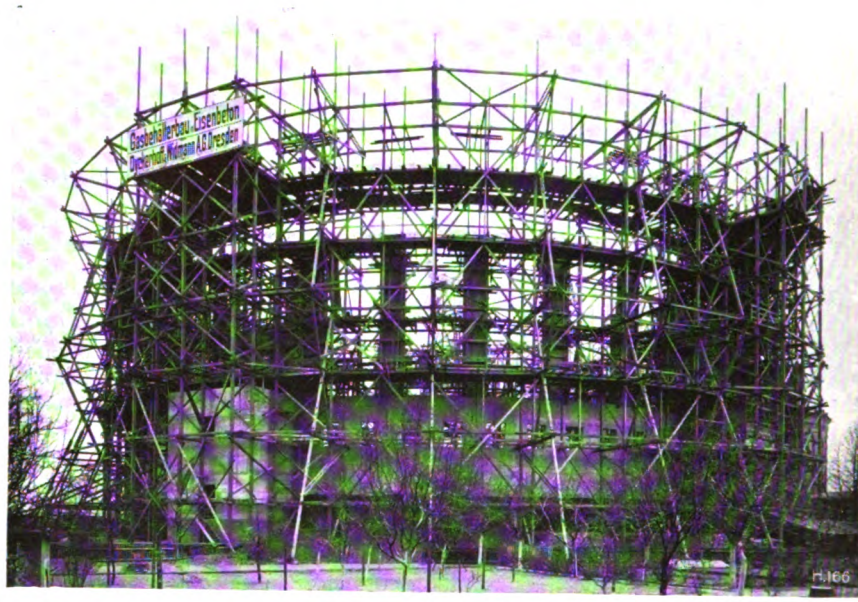
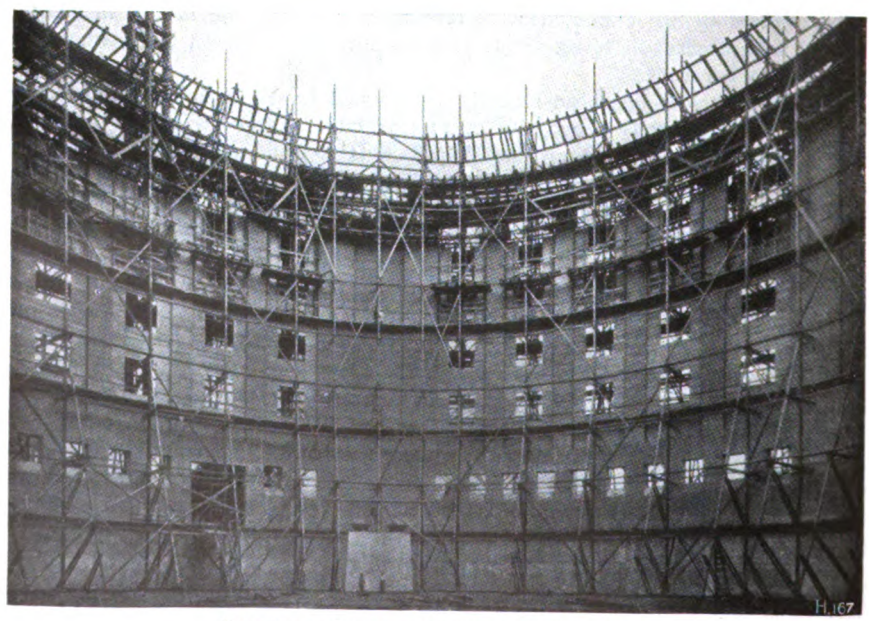


Fig. 2. External View of Timbering.



REINFORCED CONCRETE GASHOLDER NEAR DRESDEN.
Fig. 3. Internal View of Timbering.

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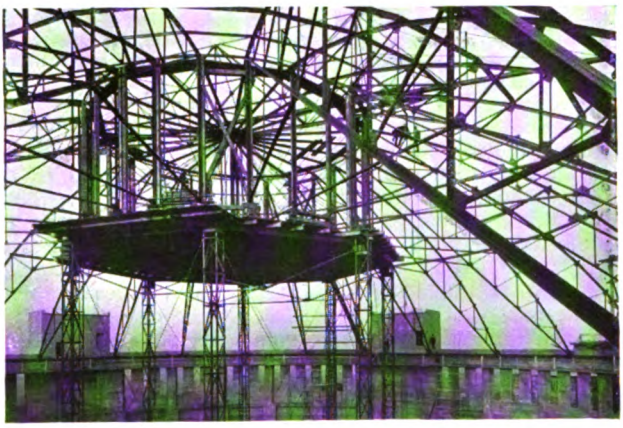
galleries, carried on corbels, aid in stiffening the structure. The cornice is a hollow one, the top being covered by special reinforced concrete slabs.

The construction of the dome is unusual. It was necessary to avoid any outward thrust on the walls and at the same time to stiffen the upper part of the cylindrical structure. This was effected by an arrangement due to the Gustavsburg Bridge Co., the designers of the steel work. The dome consists of a number of steel principals, each lying in a meridian plane and intersecting at the centre. A stiff steel ring, forming the base of the dome, is built into the cornice, and vertical angle irons are rivetted to it, in order to distribute wind stresses over as large an area of wall as possible.



REINFORCED CONCRETE GASHOLDER NEAR DRESDEN.
Fig. 5. Details of Dome and of Container.

The erection of the dome was accomplished by the use of a central 8-legged steel scaffold, materials being raised by a crane. The segments, 3 tons each in weight, were prepared on the ground, and raised to their position. The lantern is of steel, filled in with reinforced concrete panels.

When the building was complete, a slab was constructed to serve as floor within the ring, by first laying a layer of concrete 25 cm. (12 in.) thick in squares 7 m. (23 ft.) side, chessboard fashion, and then covering these squares with a layer of concrete, 4 cm. ($1\frac{9}{16}$ in.) thick, reinforced with simple crossed rods. Over the whole surface a water-tight lining was laid.

The external surfaces were treated so as to give the effect of stone. The architectural design, the effect of which may be seen from the title piece of this article, is due to the municipal architect, Hans Erlwein. The reinforced concrete was designed and executed by Messrs. Dyckerhoff and Widmann, of Dresden, who as a result of this secured the contract for erecting the iron dome roof of the Gustavsburg Bridge Building Works.

The total height of the structure from sole to lantern is 75 m. (246 ft.), and 2,600 tons of cement and 170 tons of reinforced steel were used. The construction occupied about a year, and the total cost was about £40,000, of which £3,500 was expended on preparation of the ground, £14,450 on the ring container, and £18,050 on the enclosing wall.

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED

CONCRETE WATER TOWER.

THE many good qualities of reinforced concrete make it an especially valuable material for the construction of large and small storage tanks, both rectangular and circular. Tanks and reservoirs may be buried under the ground, placed directly upon the ground, or supported at any desired elevation upon towers of steel, masonry, or reinforced concrete. The position of the tank modifies to some extent the structural details adopted as does the shape, whether rectangular or circular. The general system of reinforcement consists, however, of a network of rods, the size and spacing of the rods varying with the loads to be carried. When rectangular tanks are constructed the sides consist of reinforced slabs, sometimes strengthened with ribs or beams. The horizontal rods of circular tanks and reservoirs are spliced by lapping

ANAHEIM WATER TOWER.
(Showing reinforcements at head of tower to carry base of tank.)

or welded into hoops. The tank bottoms may or may not be reinforced, depending upon the nature of the subsoil; when they rest upon the ground they are usually approximately flat, only having enough slope to drain them properly. When tanks are elevated the bottoms are either of spherical or conical shape, usually with the convex surface upwards, although it is sometimes placed downwards.

The horizontal rings or hoops forming the reinforcement for circular tanks are placed close together and spacing gradually increased toward the top, while the vertical rods are spaced uniformly around the tank, the two sets being wired together at intersections. In rectangular tanks horizontal and vertical rods are also used and spaced similarly to those of circular tanks. At the corners formed by adjacent sides the horizontal rods are usually bent around to make the reinforcement continuous, thereby making the tank as strong at this point as at any point in the side wall. The vertical rods and bottom rods may be bent in the same manner to form a solid junction between the side walls and tank bottom.

Roofs for tanks may be either flat or ribbed slabs, spherical or parabolic arches,

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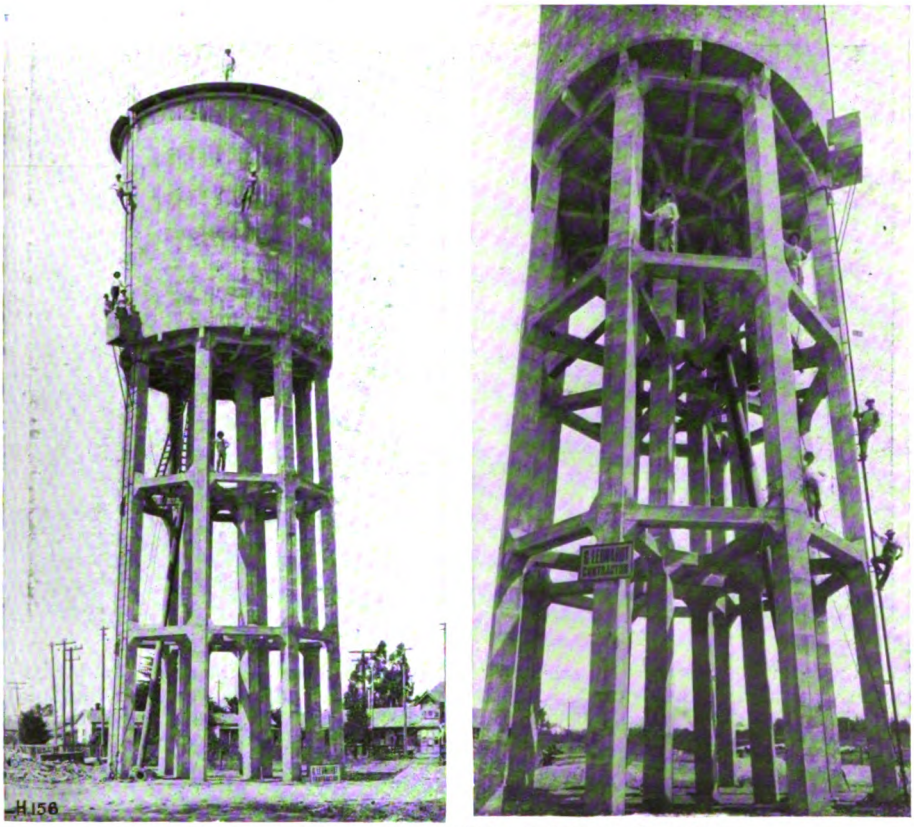
spherical arches being preferred when any great load is to be carried on the cover. For flat, ribbed slabs and parabolic arches the usual types of reinforcement are used, while for spherical arches concentric rings, with radial rods wired together, give a satisfactory means of reinforcement. The latest addition to the different construction (hydraulic) in reinforced concrete in Southern California is an elevated tank at Anaheim, Cal., built by C. Leonardt, of Los Angeles.

This tank is one of the first ever constructed in this manner, and was built for the Anaheim Water Company. It is 32 ft. dia. and 38 ft. high, supported on concrete columns 70 ft. high above the ground. It has a capacity of 200,000 gallons, and is built entirely of concrete, reinforced with square twisted steel. The walls of the tank are plain work and 5 in. thick at the bottom, and taper to 3 in. at the top.



REINFORCED CONCRETE WATER TOWER AT ANAHEIM, CALIFORNIA.

When tested it was found to be perfectly water-tight, without any cracks or leakage of any amount. The floor of the tank is reinforced with $\frac{7}{8}$-in. sq. twisted bars and supported by concrete beams radiating from the centre, and the twelve concrete columns, each 16 in. sq., are stiffened twice by two lines of horizontal struts at equal intervals above the ground. The foundation of the tank consists of a heavy concrete slab 2 ft. thick and reinforced with $\frac{7}{8}$-in. twisted steel. The tank has a conical-shaped roof of concrete 2 in. thick, with a cornice over the edge, and is slightly raised to give ventilation for the water inside. From the lowest point of foundation to the top of the column measures 112 ft. It contains 26 tons of reinforcements and 900 barrels of cement.

The plans were designed by Mr. Schank, mechanical engineer, and the detail drawings and the strain sheets were made by H. Eckardt, engineer for C. Leonardt.

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The cost of the tower was £2,280, or 25 per cent. lower than the lowest figure for a steel tower of equal dimensions.

REINFORCED CONCRETE LAUNDRY AT LOS ANGELES.

The Hygienic Laundry at 16th Avenue and most of its appurtenances have been constructed of concrete, also the soap and blueing tanks, and many of the other necessary appointments that under ordinary conditions have been made of wood, the result being in the first place perfect sanitation, concrete being non-absorbent and at all times perfectly water-tight, and with ordinary care indestructible.

The special features in this structure are the sixteen trusses used to carry the second floor and the roof. The system here adopted, while not entirely a new one, has been used already in Europe to some extent, but has never previously been used in the western parts of America. Instead of constructing these trusses in the regular

REINFORCED CONCRETE LAUNDRY AT LOS ANGELES.

way, in beam boxes supported on heavy false work, these beams were moulded flat on the ground and then raised, when the work reached that stage, and lifted into their permanent positions. All the beams are 37 in. high, those supporting the second floor are 18 in. wide, while those supporting the roof are 14 in. wide, and all are 42 ft. long over all. The second floor beams are reinforced with six $1\frac{1}{4}$-in. sq. twisted bars in the bottom cord and six $\frac{1}{2}$-in. sq. twisted bars in the top cord. The roof girders are reinforced with four $1\frac{1}{8}$-in. sq. twisted bars in the bottom cord and four $\frac{1}{2}$-in. sq. twisted bars in the top cord; all the diagonal and the vertical members of these trusses have a certain amount of steel in accordance with what the figure shows, varying from $\frac{3}{4}$-in. sq. twisted bars to six $\frac{3}{4}$-in. sq. twisted bars.

The second floor beams have a weight of 19,800 lb., and the roof girders 14,600 lb. The first beam when lifted into place had been cast for one week only, and the two last ones of the 16 were lifted after being cast only three and a half days. The whole lifting outfit consisted of two small hand winches, two gin poles, strong enough for buckling with the necessary ropes and cables, and a force of seven men. The walls are built as any other reinforced concrete walls, 8 in. thick, with the necessary reinforcement to take up the wind pressure. The columns to carry the girders were built at the same time as the wall.

The second floor is 4 in. thick with a cement finish of $\frac{1}{2}$ in. thickness, and the roof is 3 in. thick. No roofing was put on. The concrete for the roof was waterproof, and does not show any sign of leakage. The whole building was built in five weeks. The foundation was figured for 2,000 lb. per sq. ft., and the second floor for

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150 lb. per sq. ft., and the roof for 125 lb. per sq. ft. This very high figure for the roof was taken in the hope that the roof may be used some day as a floor if the business of the laundry needed another storey.

The concrete was figured in compression for columns 456 lb. a sq. in., and in the beams for 700 lb. a sq. in. The reinforced steel was with square twisted with an elastic limit of 75,000 to 80,000 lb. sq. in. The reinforcement of the walls and floors is $\frac{1}{4}$ in. sq. twisted steel, placed in accordance with what the stresses show. The building has a ventilator 60 ft. long × 10 ft., and the roof itself is a concrete slab, waterproofed, without any paper or composition roofing on it. In the test with 2 ft. of water standing for six days on this roof it did not show any leakage or moisture underneath.

REINFORCED CONCRETE FACTORY AT HARROW.

Messrs. D. G. Somerville & Co., of Victoria Street, S.W., have just erected a large reinforced concrete factory at Harrow for use by the Kodak Company, in which the "Kahn" system of reinforcement has been used throughout.

Reinforced Concrete Factory at Harrow.

From the illustrations presented it will be seen that the building comprises in one part a first floor and roof, and in other portions a first and second floor and roof.

The building measures 337 ft. by 39 ft. $7\frac{1}{2}$ in., the floors and roofs are supported by a row of columns down the centre of the building, and across these run the main beams of the first floor, which have a bearing on the exterior walls, these forming floor bays of 39 ft. $7\frac{1}{2}$ in. × 16 ft., the floor slab being 4 in. thick, with intermediate beams or joists spaced at 6 ft. 6 in. centres.

The roof and portions of roof forming the second floor are constructed by having one centre main beam supported by columns, the floor slab is in a 20-ft. span from the centre beam to the external wall on either side, and is constructed of hollow tiles with 4-in. spaces. Concrete is filled into these spaces, and they also contain the reinforcing bars. Thus a small reinforced concrete beam is made between every row of tiles, the whole being covered with 2 in. of concrete. For the higher portion of the roof a construction similar to that of the first floor is used.

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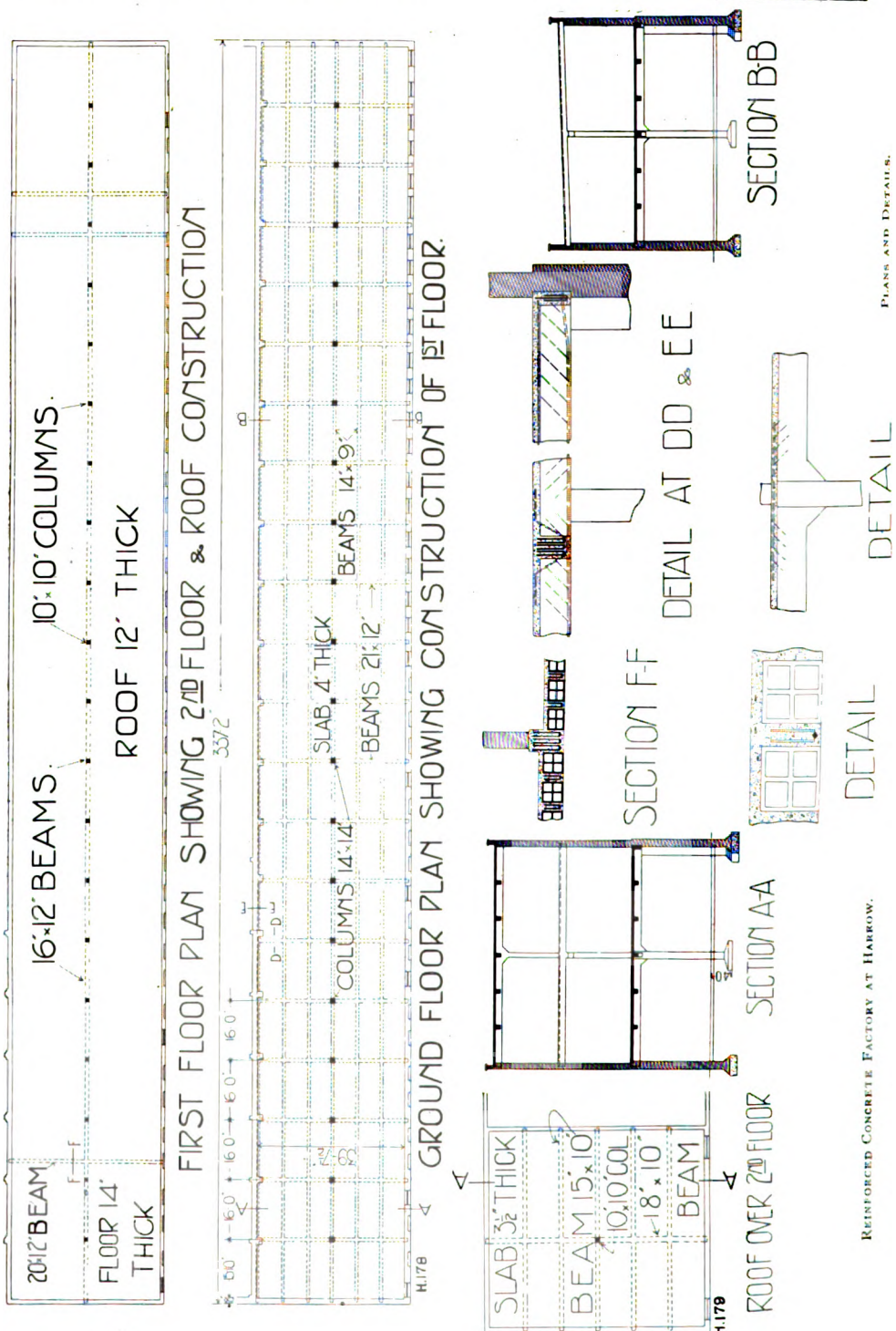

Plans and Details.

Reinforced Concrete Factory at Harrow.

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NEW USES FOR CONCRETE

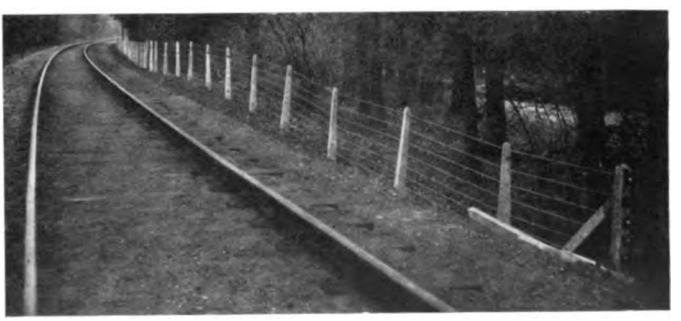
AT HOME AND ABROAD.

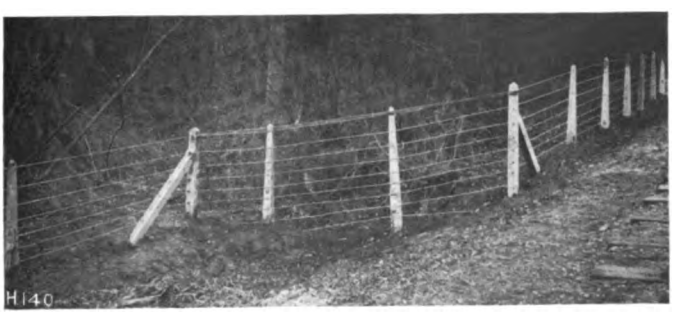
Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

REINFORCED CONCRETE FENCE POSTS.

In our March issue we presented some illustrations and particulars of reinforced concrete fence posts made and erected by Mr. E. F. W. Grimshaw, at West Mill, Buntingford, Herts, and elsewhere. We have since been pursuing inquiries into the relative merits of wooden fence posts as now in use on most, if not all, the English railways, and the results of our investigations show a great advantage in favour of concrete. We are enabled to give approximate figures, and these also prove conclusively the immense advantages over wooden fence posts.

Working upon a mile of railway fencing, the cost per yard for new wooden fence posts of the cheapest description is about 1s. 4½d. per yd. run complete, whilst the cost for new concrete posts would be 1s. 9d. per yard run complete. After being in use for ten years, and thus subjected to the weather, the wooden fence is practically worn out, although some authorities give the life of a wooden fence about twenty years. At the end of that period the concrete post is as good as new. Thus at the commencement of the eleventh year there is a saving of 0d. per yd., which for 1,000 miles of system (taking the fence on each side) is calculated to cost about £132,000.





Some Reinforced Concrete Fence Posts.

We can assume, however, that at the end of 20 years the concrete posts are still useful, but that the intermediate wires require renewing- although wire will last about thirty or forty years in the country. Taking the wire at 4d. per yd., and labour for same at 2d., this would represent £45,000 in 1,000 miles of system, or £90,000 on both sides of the line. Calculating on an ordinary basis the wood fences will, at the commencement of the first twenty years, have cost three times 1s. 4½d., say 4s. 1d. per yd., while the concrete posts will still be 1s. 9d. plus 6d., or 2s. 3d. per yd. Accordingly, there is a saving of 1s. 10d. per yd., or, roughly, a saving of £310,000 in 1,000 miles at the end of twenty years, allowing £10,000 interest on extra first cost. All of this is working on the assumption, of course, that the fence post of concrete will stand weathering during the period named.

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There is no reason to suppose that the ordinary upkeep of either fence is much different, except in one very important point, and that is burning. A considerable amount of time is spent every year by railway men in digging along the fence to clear grass, etc., away, which must cost a great deal of money in labour, though

FIG. 1. REINFORCED CONCRETE PIPES AT PARIS.

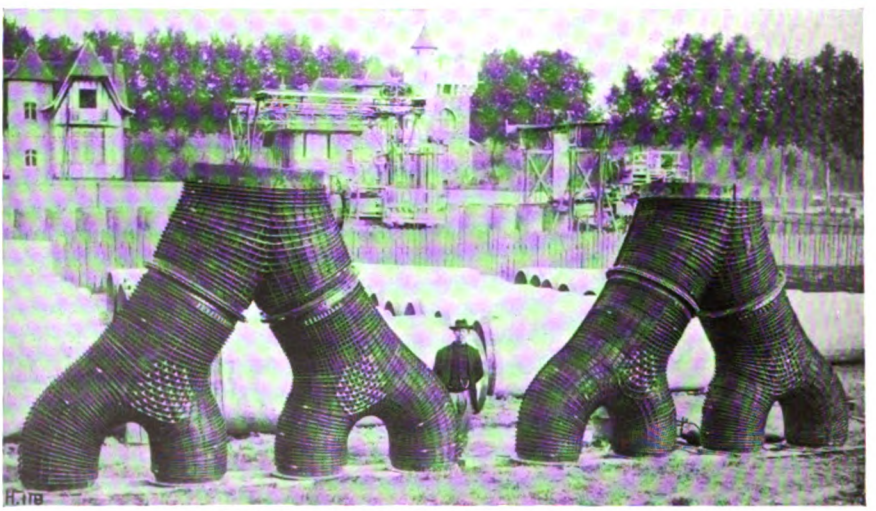

FIG. 2. REINFORCED CONCRETE SPECIALS FOR A PIPE LINE AT PARIS.

this point is not directly felt in regard to fences, but it is there all the same, and in spite of this care and clearing a large number of posts on railways are burnt every year. The preservative used on wooden posts increases the risk of burning.

The risk of posts being broken is a big one. The durability of concrete over wood is hardly comparable, and there should be no more reason for a new reinforced con-

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crete post breaking than a wooden one. As a matter of fact, after a few years the concrete is stronger than when new, whereas wood weakens year by year.

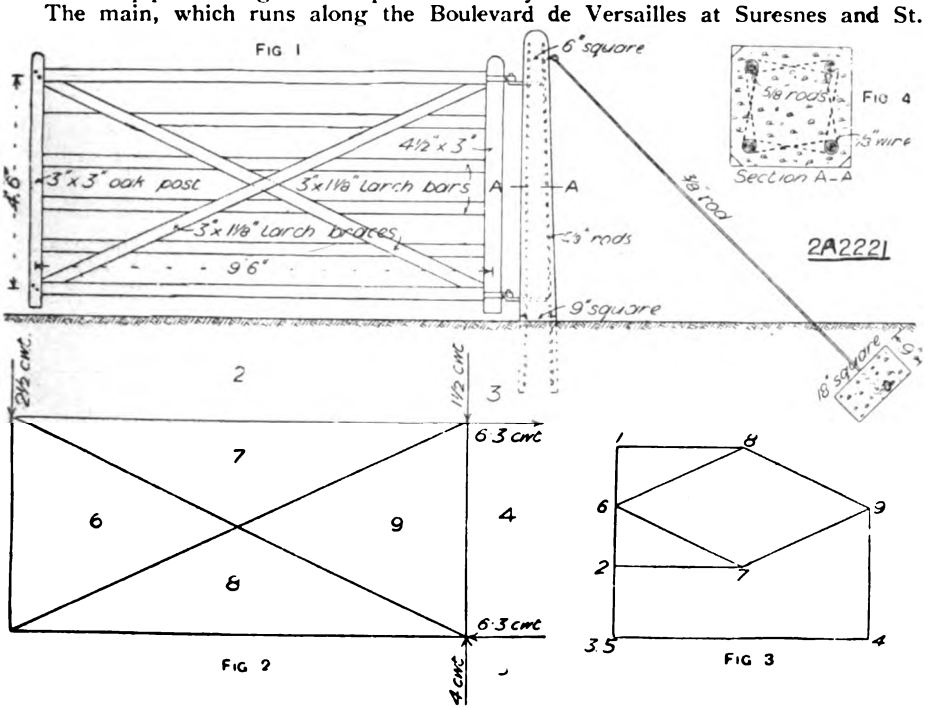
CONCRETE PIPES IN FRANCE.

The Corporation of the City of Paris, who were the first to employ reinforced concrete pipes some years back, are now having a water main laid down for doubling the supply from the Avre wells. This main will run from the reservoir at St. Cloud to the Ternes Gate of Paris, a distance of no less than 4¼ miles, and is to work in most parts under an average pressure head of 280 ft.

The Bonna pipes here used are composed of an interior steel tube ⅛ in. thick, coated on the inside and outside with concrete, armoured with † steel spirals and bars.

They are manufactured and moulded in a yard not far from where the pipes are being laid, being so manufactured that hand labour is reduced to a minimum, yet the finished pipes are regular and perfect in every detail.

The main, which runs along the Boulevard de Versailles at Suresnes and St.



A Reinforced Concrete Gate Post.

Cloud, is divided into four branches, 24 in. in diameter, to cross the Suresnes Bridge. Here it enters the Bois de Boulogne, through the Avenue des Moulins, passes the Cascade, and runs along the beautiful Avenue de Longchamp to the Porte Maillot. There it crosses the Neuilly-Porte-Maillot Square, under ten tramway metals, to finish at the Ternes Gate, after running through a gallery under the Paris circular railway.

The pipes are 14 ft. long, laid butt to butt, and joined together by a special system, designed to resist high pressures. Covering this joint is a ring in reinforced concrete, with internal steel tube, which thus reinforces the pipe and adds to its resistance. All the "specials," such as manholes, airholes, bye-passes, etc., are also executed after Bonna's system. The crossing of the river Seine under the Suresnes Bridge has necessitated the construction of a "special" shown in *Fig.* 2, which has proved a complete success.

A REINFORCED CONCRETE GATE POST.

Prof. Henry Adams, M.Inst.C.E., in a recent issue of the *Building World*, gave the following design and particulars of constructing a reinforced concrete gate post.

The elevation of the gate being as shown in *Fig.* 1, the frame diagram will be as shown in *Fig.* 2. Taking the weight of the gate at, say, 3 cwt., and allowing

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for a boy weighing 1 cwt. swinging on the end, the loading will be as shown, and the stress diagram as shown in *Fig.* 3. The gate post may now be calculated as a cantilever of 4 ft. 6 in. effective length, with a pull of 6·3 cwt. at the top. Let W = pull in cwts. at the top, p = percentage of reinforcement, L = length in feet, b and d = breadth and depth in inches. Then $W = \frac{(\cdot 37p + \cdot 214)\, b\, d^2}{8L}$ or $6{\cdot}3 \times 8 \times 4{\cdot}5 = (\cdot 37p + \cdot 214)\ b\ d^2$, whence $(\cdot 37p + \cdot 214)\ b\ d^2 = 226{\cdot}8$, which would be given by a post 8 in. sq. with 1 per cent. reinforcement; but the post may be made 9 in. sq. at the ground level, and 6 in. sq. at the top, with the batter on one side only. The reinforcement will consist of a $\frac{5}{8}$-in. rod at each corner, bound by wire at 6-in. intervals, or spirally, as shown in Fig. 4. The post may be carried down 3 ft. into the ground without any backstay, or 18 in. with an anchor block as shown.

We are indebted to Messrs. Cassell & Co. for the use of the illustration.

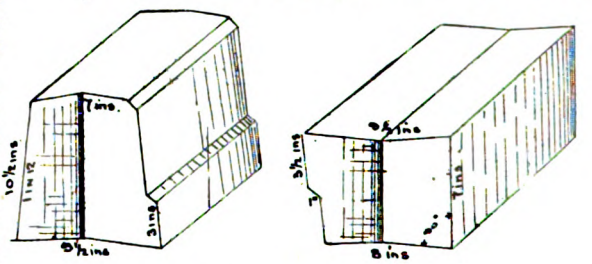
CONCRETE KERB AND CHANNEL BLOCKS.

The question of concrete kerbs is one that is engaging the attention of municipal engineers, and we present particulars of what may be termed Fenwick's kerbs and channel blocks.

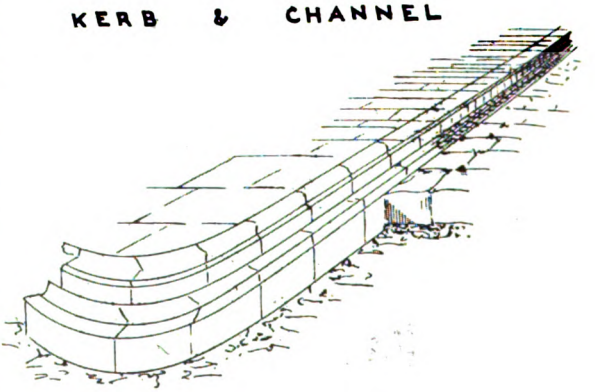
Fenwick's design for concrete kerb and channel blocks is to obtain a result that could only be done in stone at an entirely prohibitive cost. The kerb has a projection on the outer face on which the channel block is so formed as to find a rest and supports, this and the "joggle" joints will keep the blocks in position, and will preserve a rigid line for either paved streets or macadam roads. The blocks are designed with a batter to give breadth of bed; they will leave the moulding box more easily for this.

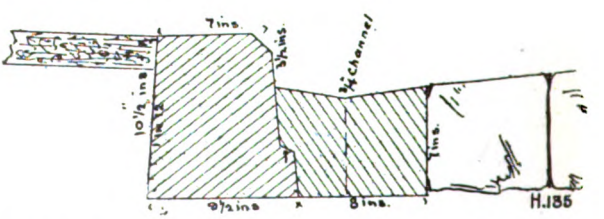
The channel blocks being of lighter section should be made longer than the kerbs in order to break joint, they are "dished" three-quarters of an inch on the upper surface.

The kerb may be used separately or with the channel blocks; the surface is less slippery than stone kerbing, and the cost will compare very favourably with worked stone blocks.



KERB & CHANNEL





RAILWAY CULVERT AT BROMBOROUGH, CHESHIRE

One of the largest railway culverts ever commenced in this country has just been started for Messrs. Lever Brothers, at Bromborough, Cheshire. It consists of covering in two small streams and carrying them on to a larger one, also covered in. The span of the latter is 19 ft., and the calculated load to be carried on it is 20 tons per lineal foot. The main culvert is then carried a considerable distance down stream, and finished at each end with wing and retaining walls.

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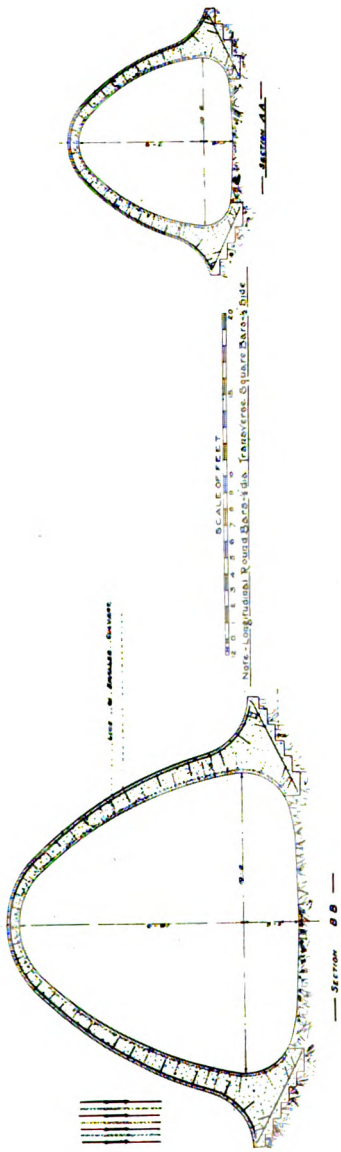
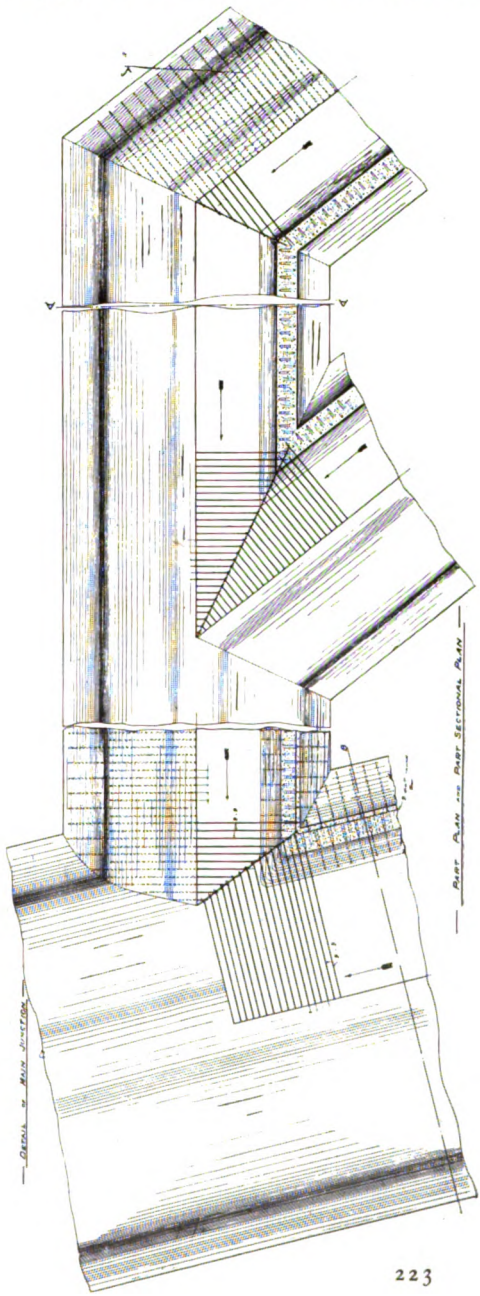
The photograph presented explains itself, and the culvert affords a good example as to the application of the Paragon system of reinforcing, which consists of plain commercial bars and patent self-gripping stirrups (of high carbon steel), which, when the arms are released, maintain a mechanical grip in their exact position on the tension bar.

The engineers for the scheme are Messrs. Wm. & Segar Owen, of Warrington, whilst the British Reinforced Concrete Engineering Co., Ltd., of Deansgate, Manchester, etc., are the patentees who supply the reinforcements. The contractor is Mr. L. P. Nott.





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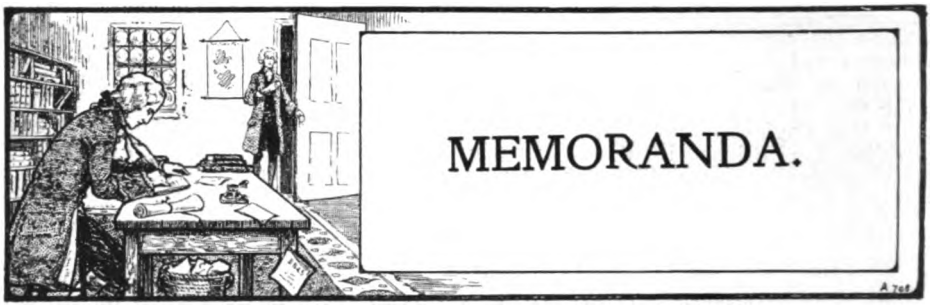

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

BOOKS.

"The Portland Cement Industry from a Financial Standpoint."—This work (from the pen of Mr. Eckel) deals at considerable length with the progression of the cement industry in the United States from its commencement to the present time, together with the location of the plants, and gives voluminous statistics as to output and selling prices, together with a forecast of the future of the industry and advice to investors as to participating in future issues of debentures and shares of new companies. With regard to advice to investors, the writer follows *Punch's* advice to those about to marry—"don't." He points out that although the increased uses of cement are many, and the demand in the United States is of very rapid growth, yet the erection of new works is already on a greater scale than such demand warrants. Those who carefully study the pages of Mr. Eckel's work are hardly likely to assist financially in the further development of the industry.

There is no allusion whatever to the slag cement companies or their possible adverse effect upon the Portland cement trade. It is well known that very large sums of money have been paid by Americans for some of the numerous cement patents (made in Germany) for manufacturing cement from slag. We must suppose from Mr. Eckel's ignoring these concerns that he does not look upon them as of any importance in the future of the American cement industry, and this is of interest, seeing that Mr. Eckel s one of the principal authorities in the United States on the cement industry, and his work on "Lime and Cement" is one of the standard books upon the subject.

LECTURES.

Reinforced Concrete Construction.—Mr. G. C. Workman, C.E., Managing Director of Messrs. Edmond Coignet, Ltd., gave a lecture on reinforced concrete construction, dealing more particularly with the Coignet system, before the Incorporated Clerk of Works Association of Great Britain, recently at Carpenters' Hall, by special request. Mr. Joseph Davis presided. The lecturer dealt principally with the practical side of the question, and illustrated his remarks by a large number of lantern slides, which showed works executed on the Coignet system in Great Britain and abroad. Several model steel frameworks were exhibited and explanations were given concerning the theory of beams.

Society of Engineers.—Mr. W. E. Haldwell, B.A., M.S.E., read a paper on the Sinlumkaba (Burma) Reinforced Concrete Bridge before the members recently. Owing to pressure of space we are compelled to hold over Mr. Haldwell's remarks until our next issue.

GENERAL.

Liverpool Corporation and Reinforced Concrete.—Liverpool Corporation secured a General Powers Act last Session in Parliament and Section 27 allows the Corporation to relax or modify the provisions of any Acts in force in the city regulating the construction of buildings in favour of persons desirous of erecting an iron, steel, or reinforced concrete building, or any building to which the general provisions of such Acts are inapplicable.

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Concrete Caissons.—An ingenious system is being adopted for the construction of the quay walls of the new harbour at Kobe, Japan. The walls are to be built of reinforced hollow concrete monoliths measuring 120 ft. by 26 ft. by from 32 ft. to 41 ft. high, which must be moved considerable distances from the building yard to the site of the works, and will then be filled up solid. To facilitate their transport a floating dock is being constructed to the designs of Messrs. Clark & Stansfield. The blocks will be moulded on timber stagings built along the foreshore, and will be hollow, with sufficient displacement to float of themselves. When the concrete has matured they will be lifted off the staging by the special floating dock, taken into deep water, allowed to float off the dock by sinking the latter, and then towed to their destination. When in place, they will be forced to sink by admitting water into the interior, which is divided by bulkheads into separate compartments, so as to allow the sinking to be controlled. The reinforced concrete shells will then be filled up with coarser concrete, and probably the different blocks keyed together, so as to form a monolith of the complete quay. The block yard will be sufficiently large for the accommodation of six blocks in various stages of construction, and, allowing three months for the moulding and ripening of each block, the seventy blocks, which comprise the entire scheme, could be completed and deposited in about three and a-half years by the aid of a single depositing dock.

Reinforced Concrete in Jamaica.—Among the many valuable attributes of reinforced concrete as a constructional material is its capability of withstanding the effects of earthquakes. This property has lately been taken advantage of in the building of some new premises for the Bank of Nova Scotia in Kingston, Jamaica, where it was, of course, of the utmost importance that the offices should not collapse in case of an earthquake. The contract, which was carried out by the Walker-Fyshe Company, of Montreal, Canada, included a two-storey building measuring 150 ft. by 75 ft., in which there is a main banking room the full width of the building by 60 ft. deep. The ceiling of the large room is supported by steel trusses carried on columns independent of the walls. The remainder of the work was carried out entirely in concrete reinforced with indented steel bars. The concrete was composed of one part of cement, two of sand, and four of stone, broken to pass a 1-in. ring. Unusual precautions were taken in arranging the reinforcement in order to bind the building thoroughly together. Thus the bars in the walls of the first storey were continued up into those of the second storey about 3 ft., and at all corners the bars were bent round with a lap of from 18 in. to 24 in. The main walls are 18 in. and 24 in. thick, and are reinforced on both sides with vertical and horizontal bars spaced 9 in. centres both ways. The partition walls are 4 in. thick. The floors and roof are also of reinforced concrete. The foundations are very heavy, and spread out to keep the pressure on the subsoil down to 3,800 lb. per sq. ft. Thus, it will be seen, the building forms a monolithic mass very well suited to resist earthquakes.

Reinforced Concrete in the "Hous".—Mr. Remnant asked in the Parliamentary Papers if the construction of the new General Post Office in Newgate Street was to be executed entirely on the Hennebique system of reinforced concrete; if other systems were examined before the adoption of the Hennebique; and were any or all of the articles used in this system made in England. Mr. Harcourt replied that the entire structure, with exception of the street façades, which are of granite and stone, was of reinforced concrete on the Hennebique system, and that part of the work was now practically completed. Other methods were examined before the Hennebique system was decided upon for this building.

Tests Congress.—The fifth Congress of the International Association for Testing Materials will be held in Copenhagen, under the patronage of the King of Denmark, from September 7 to 11 next. The programme of the various sections includes cement, stones, concrete, reinforced concrete, and progress in the methods of testing.

Reinforced Concrete Railway Sleepers.—Last autumn the State Railways of Italy placed with a Rome house a contract for 300,000 reinforced concrete sleepers. These have been so satisfactory that a second similar quantity has been ordered. The price is 6s. each.

Warrington Bridge in Reinforced Concrete.—After years of discussion and postponement, the Warrington Town Council decided to re-erect the Warrington Bridge in reinforced concrete.

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DEMONSTRATION.

The Kleine Patent Fire-Resisting Flooring Syndicate, Ltd.—Before breaking up their exhibit at Olympia, this firm gave an interesting demonstration showing the effect of heavy loads falling from a height on their floor which had only been constructed 20 days, and had not attained its full strength. A stone weighing 90 lb. was dropped from a height of 10 ft. on to the centre of the floor, measuring 20 ft. by 12 ft., the clear span between girders being the latter dimension. After repeated falls on the same spot—about 15 in. square—a hole was knocked through the floor, the stone remaining suspended on the tension-bands. Similarly, a round shot weighing 30 lb. was dropped from a height of 18 ft. on another part of the floor, the effect being much the same as in the case of the falling stone. Against the side of the floor—consisting of one of the 9 ft. by 4 ft. girders, into which the floor was built—a fine glass measuring-tube was placed between an upright wooden support, so that the least thrust or pressure on the steelwork would break the glass. There was also an ordinary hen's egg laid on the concrete surface of the floor, a few feet from the spot on which the large stone was dropped, so that the least vibration would crack the egg. On examining the structure after the test, it was found that every portion of the floor, except the small spaces on which the weights had fallen, was quite unharmed, and neither the glass tube nor the shell of the egg showed any fracture. Noteworthy was the absolute cohesion of the cement-mortar joints in which the iron tension-bands are embedded. Although comparatively green, after 20 days not a sign of severance or loosening of the joints was to be seen anywhere, even in close proximity to those parts of the floor on which the weights had fallen.

NEW MACHINERY.

Agricultural Concrete Pipes.—A new and practical hand machine for the manufacture of agricultural concrete pipes has just been placed upon the market by the "First Cottbus Cement Goods and Machine Works," whose London representative is Mr. R. H. Baumgarten, of 1 Laleham Road, Catford, S.E. The makers claim that by their special process an absolutely impervious pipe can be produced at an extremely low cost.

Building Block Machines.—The Stockton Stone and Concrete Co., Ltd., of Norton, near Stockton-on-Tees, have put on the market Dring's Patent Building Block Machines, a new invention for the manufacture of any kind of hollow or solid building blocks up to 2 ft. 8 in. in length by 9 in. thick by 10 in. high. The chief features of the machine are its strength, simplicity, durability and ease of operation.

CATALOGUES.

Messrs. John Barke. have sent us a well-illustrated booklet descriptive of the "Kennedy" patent bending machine. Compact, portable, and simple, it should be useful for reinforced concrete work. It is eminently adapted for bending tubes or rods of various sections cold, and nullifies the use of stock elbows, bends, and sockets. The machine is made in various sizes and for different classes of work. Full particulars may be obtained from Messrs. Barker's engineering department, Kensington, W.

Messrs. Sideolith, of Temple Street, Birmingham, have sent us a small scale model of their "Skeleton Steel" reinforcement employed for bedding in concrete lintols, beams, floorings, steps, etc. They claim to give the maximum of metal, as it is stamped out of single strips of steel or rolled sections, and has no separate parts to become misplaced. In addition to undertaking complete works in reinforced concrete, "Sideolith" supply individual features required in the construction of buildings, chiefly consisting of lintols, beams, columns, flooring, roofing, etc., which are suitable as substitutes for iron or steel. They state they have also organised an advisory department in reinforced concrete constuction.

The United Kingdom Fireproofing Co., Ltd., have sent us a most beautifully produced catalogue indicating their systems of construction and illustrating quite a number of buildings on which they have done work. The printing of this catalogue, which has been produced on the loose-leaf principle, is quite above the average, and the fact that the illustrations are on one side of the page only is eminently practical. The details of construction are very clearly shown, and in addition to photographs we find some useful working drawings. Of these working drawings, one dealing with the cantilever balconies of a race-course stand is of especial interest.

CONTRACTS.

The following lists of contracts entered into are prepared from the statements transmitted to this journal by the firms mentioned below:—

The British Reinforced Concrete Engineering Co.—Railway culvert scheme at Bromborough; water tanks at Manchester and Darlington; bridge in Northumberland; warehouse in North Wales; floors at Cononley and Maesycoed Schools; mill in Ireland; water tower and tank near Leeds; club premises at Nottingham.

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CONTRACTS—*continued.*

The British Uralite Co. (1908) Ltd. have recently supplied 4,000 ft. for a laundry in North London; and 12,000 ft. for panels on the South Eastern Railway. In addition, they have supplied about 100,000 ft. for some chemical works in Yorkshire; 8,000 ft. for station on the South Eastern Railway; 35,000 ft. of Uralite for a factory in Hull; 9,000 ft. to the Ipswich Malting Co.; 12,000 ft. for a motor garage in Egypt.

Coignet (Edmond), Ltd.—Extensions to Soap Works at Chiswick and to Erith Oil Works; bottling store, Dartford Brewery; dolphins for the Admiralty at Portland; new floor at Newington Sessions House; new golf club, Leeds; extension, Maternity Hospital, Leeds; box store and accumulator house, York; two bridges at Saltley; new baptistry, Headingley, Leeds; Caerphilly Schools, South Wales; and other smaller contracts.

Columbian Fireproofing Co., Ltd.—New post office, Oxford Street, W.; new buildings, Austin Friars Square, E.C.; schools at Dartford and Colchester; theatre, Wallsend; school of art, Liverpool; bridges for Caledonian Railway Co.; reinforced concrete staircases, Glasgow; new premises at Anniesland, Scotland; asylum for the blind, Glasgow; baths, Burnley; reinforced concrete pipes at Grays (Essex), Clydebank, and Belfast.

R. Johnson, Clapham & Morris, Ltd.—Geelong Harbour Trust (Victoria), Pacific Phosphate Co. (Ocean Island); school, Newbury; blocks at H.M. prisons at Borstall, Maidstone, Winchester; new warehouses at Liverpool and Greenhithe; extensions to brewery, Melbourne; hotel, Maldon (Australia); commercial travellers' club, Sydney, N.S.W.; warehouses, Jamaica, Calcutta, Bombay, Rangoon; warehouse floors, W. Maitland, N.S.W.; floors for Naranderra (N.S.W.) Hospital; brewery, tank, woollen mills, storm water channel, and telephone exchange floors, all in various parts of Sydney, N.S.W.

Patent Indented Steel Bar Co., Ltd.—Schools, Sheerness and Ramsgate; malting floors, Burton-on-Trent; Badminton court, and infirmary floor, Aberdeen; water towers, Rhyl and Leicester; reservoirs, Liss, Grimsby, and Fermoy; warehouses, Birmingham and Coventry; bridges, Somerset and Bombay; roof, Folkestone; tank, Grayshott; galleries, Hull cattle market; motor garages, Highgate and Leicester; sewage works, Durham; baths, Hull; Metropolitan Railway extensions, Vine Street and Dollis Hill; retaining wall, Cheapside, London.

United Kingdom Fireproofing Co., Ltd.—Reinforced concrete stands, Doncaster Racecourse reinforced concert pavilion, Newquay; floors and steelwork, Doncaster, Nelson, Glasgow, Horseferry Road (London), power station (Manchester), and other smaller contracts.

Vulcanite, Ltd., recently shipped a large consignment of vulcanite sheet asphalte and Rexilite bitumen sheeting, combined with vulcanite composition, to Rosario for the Consolidated Waterworks Co., for waterproofing their large new concrete reservoir.

CORRECTIONS.

Cement Slab Patents.—We regret that in our report of the recent decision on the revocation of British patents worked abroad, published in our May issue, we referred to Messrs. Coignet as defendants. This, of course, should have been L. Hatschek.

The Society of Architects.—In our summary of the paper read by Mr. B. B. Butler, A.M. Inst. C.E., before this Society on "The Dangers of Breeze Concrete," which was published in our May issue, the word "than" should have been omitted in the final sentence of the penultimate paragraph. It should have read thus:—The experiments showed that many of the specimens which indicated a marked expansion when placed under water, expanded much less when left entirely in the air.

EDITORIAL MEMOS.

CONTRIBUTIONS.—Original contributions and illustrations are specially invited from engineers, architects, surveyors, chemists, and others engaged in practical or research work. MSS. should be written on one side of the paper only, giving full name and address of the author.

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PUBLISHER'S NOTICES.

DATES OF ISSUE.—This Journal is issued bi-monthly, in January, March, May, July, September, and November. Advertisements required by 10th of month prior to subsequent issue.

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MISCELLANEOUS WANTS

PATENT.—The proprietor of Patent No. 545 of 1904, relating to improvements in Crib work and the like, desires to enter into arrangements, by way of license or otherw se, on reasonable terms, for the purpo e of developing and practically work ng the same in this country.—Enquiries should be addressed to W. P. Thompson & Co., Chartered Patent Agents, 322 Higb Holborn, London, W.C.

CONCRETE BOOKS at GREAT REDUCTIONS.—New Books at 25 per cent. discount. Books on Concrete, Engineering, Building Construction, Technical and all other subjects supplied. Sent on Approval. State wants. Send for Lists. Books purchased — W. & G. FOYLE, 135 Charing Cross Road. London, W.C.

AGENTS.—One of the leading firms of Reinforced Concrete and Fireproofing Specialists is open to appoint agents in the following districts: Bristol, Brighton, Cardiff, Exeter, Norwich, Northampton, Nottingham, Manchester, Portsmouth, Reading, Truro. Preference given to firms or individuals having established connection among Architects and Engineers. Apply with full particulars Box No. 53, "CONCRETE AND CONSTRUCTIONAL ENGINEERING," Dewar House, Haymarket, London, S.W.

"IDEAL" Hollow Concrete Block and Sill Machines; "Ideal" Cement Sand Brick Machines; Hand or Power Concrete Mixers; Special Machines for Concrete Flags; Sewers or Drain Pipes; Fence Posts; Gates and Gate Posts; Sleepers; Telegraph Po'es and Arms; Channels, etc.; write for particulars.—JOHN PICKLES AND SON, Engineers, Hebden Bridge.

OLD IRON DOORS. SECOND-HAND IRON DOORS REQUIRED, hanging or sliding immaterial, any width from 2 ft. to 7 ft. Must comply with London Building Act.—Apply in writing, stating sizes, frames (if any), bolts, latches, to E. R., Box 5881, Willing's, 125 Strand, W.C.

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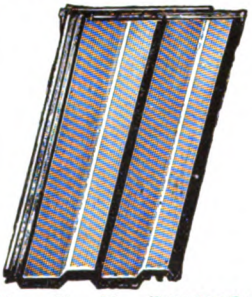

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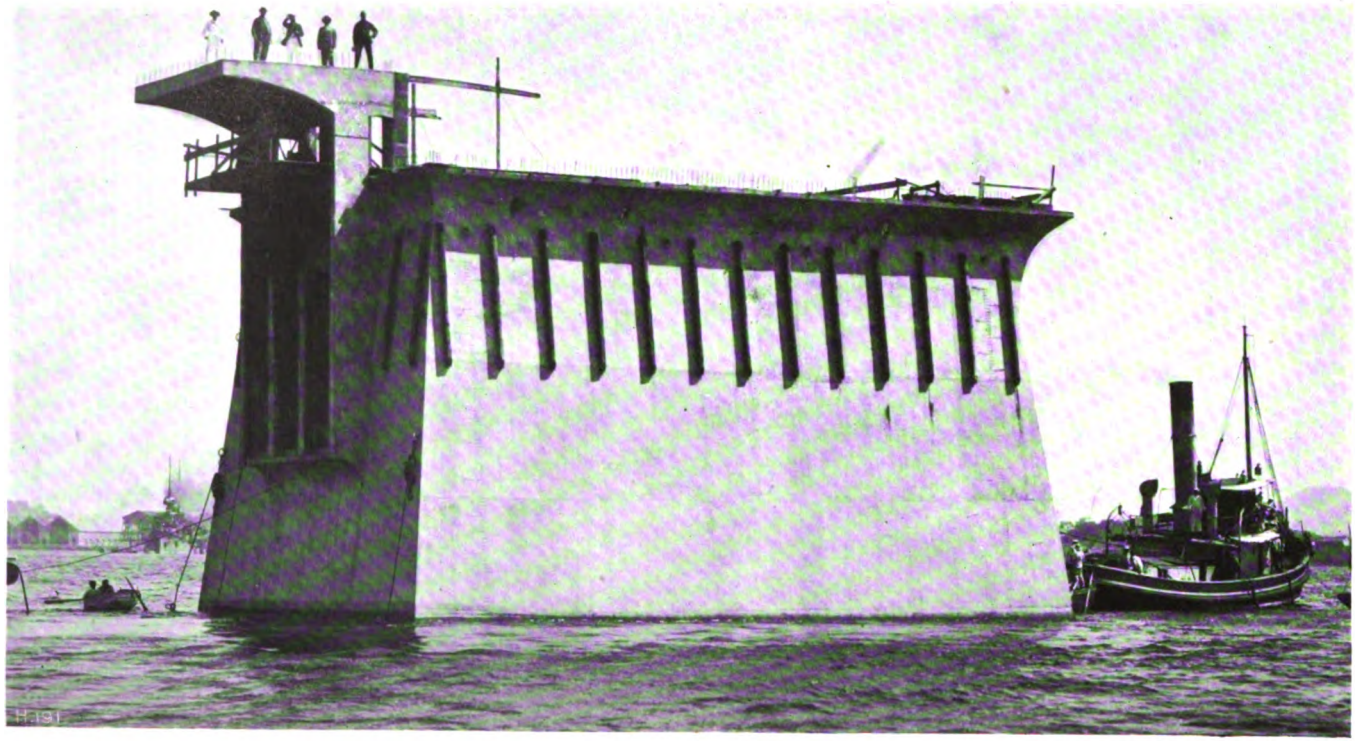

TOWING A REINFORCED CONCRETE CAISSON TO ITS MOORINGS.
(*See Article on a Reinforced Concrete Torpedo Station, page* 247.)

Frontispiece (228).
(*Opp. Contents.*)

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume IV. No. 4. LONDON, SEPTEMBER, 1909.

EDITORIAL NOTES.

OUR NEW DEPARTURE.

It may be remembered that this Journal was founded in March, 1906, with the object of meeting, primarily, a demand for reliable technical and economic information regarding concrete and reinforced concrete.

For more than three years this Journal has been before its readers as a bi-monthly, and there appears to have been throughout that period a consensus of opinion, both in professional circles and in the industries concerned, that this Journal fulfilled its object.

Only in one direction have there been strictures—namely, regarding the infrequency of its appearance, the interval of two months between each issue being considered an unduly long one.

In the three years during which this Journal has been published the advance in the uses of concrete, and the application of reinforced concrete in particular, has been extraordinary, and this development has brought with it a very considerable addition in the amount of information that can be presented—*i.e.*, information of the character in which this Journal has made a speciality—namely, scientific and practical data that are not only really useful to the reader at the time of publication, but also valuable to have at hand at all times for reference purposes.

Having regard to this, the development of our subject, the character of the information available and the repeated suggestions of our readers, both at home and in the distant parts of the Empire, we now have pleasure in announcing that henceforth

THIS JOURNAL WILL APPEAR AS A MONTHLY.

We trust that the same support as was accorded it as a bi-monthly will be given this Journal as a monthly; in fact, we expect yet greater support and a yet greater field of utility for the Journal.

OUR EXTENDED FIELD OF UTILITY.

As the pioneer journal devoted to concrete and reinforced concrete in the British Empire, it is further hoped that this Journal in its extended form will be of special use, not only to those directly, technically, or industrially interested, but also to those many building owners and employers of labour who desire to obtain practical information on everything that may tend to economy in the erection and maintenance of the structures in their charge. Appearing at shorter intervals, the contents of this Journal may assist in popularising the subjects among a far wider field of users than was possible when its appearance

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at long intervals gave the Journal something of the character of an academic quarterly.

In style and scope little or nothing is, however, to be changed except perhaps in one respect—namely, that the illustrations are to be even more numerous than heretofore.

This Journal is to continue to enjoy the best technical assistance obtainable, and there will be no parsimony where expenditure is necessary for the presentation of the latest available data from pens of undoubted authority.

OUR POLICY AS AFFECTING THE INDUSTRIES CONCERNED.

As to this Journal's general policy we would only recapitulate that, in advocating the extended use of concrete and the application of the most up-to-date principles of constructional engineering, stress will be laid on the absolute importance of using none but the best of materials and work, and as such excellent materials and work are produced by leading British firms everything possible will be done to further the specification of British material and the employment of British labour. Although no insularity will be observable when useful ideas of foreign origin come under review—and, in fact, the application of such ideas may be energetically advanced—this Journal will call attention to any unnecessary use of foreign material or employment of foreign labour, particularly in respect to works carried out under the auspices of the Government and municipalities with the money of the British taxpayer and ratepayer. Those conducting this Journal go so far as to consider that on property under the control of Government departments and public bodies generally preference should always be given to work and material obtainable within the British Empire; in fact, they hold that where British work and material are obtainable at reasonable prices nothing else should be utilised by our public authorities.

The various industries associated with constructional engineering and concrete, be they represented by the manufacturers of cement, the producers of structural steel, or the purveyors of special systems of construction, will find in this Journal an exponent of the difficulties under which they frequently have to work, to the detriment of good construction, to the disadvantage of the British worker, and to the loss of the State. This Journal will, in fact, be a strong supporter of the home industries affected, and it is to be hoped that its efforts may be of some assistance, not only in the advancement of sound and economical work generally, but more particularly of such work as is entirely British.

LECTURES AND PAPERS.

We observe with considerable interest that the number of papers read before technical societies, and dealing directly with concrete, reinforced concrete, and their constituents, is increasing.

It has been our practice hitherto to give only short summaries of lectures under our heading of "Memoranda," limiting ourselves to a more extensive summary in the case of papers presented before the Concrete Institute.

Recognising the importance of this journal—as the only representative one in Great Britain devoted to concrete and reinforced concrete, etc.—supplying our readers with all available information on those subjects for which CONCRETE

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was founded, we take with this issue a further step in recording such papers. which step, we are sure, will be welcomed by our readers.

In future, under the heading of "Recent Views," will be found reports of the more important papers presented to the different technical bodies. Each paper will be summarised—length being governed by its importance—and will contain side-headings in bold type, which will make it easy for subsequent reference. The papers thus presented will be those dealing with new views or recent opinions.

As occasion warrants descriptive papers with illustrations will also be dealt with as special articles.

THE INTERNATIONAL COMMISSION ON REINFORCED CONCRETE.

THE International Congress for Testing Materials will commence its proceedings on the 7th inst., at Copenhagen, when not only will there be a large number of members present, but there will also gather the special commissions and special committees connected with the work of the International Testing Association.

The importance of the testing of materials cannot be sufficiently recognised in this country where there has, unfortunately, long been a tendency to neglect this very necessary feature in scientific progress.

Gatherings such as the one now imminent, produce an enormous amount of valuable information, and they also give an opportunity to those interested in kindred subjects to informally discuss the points at issue.

The occasion of the Congress will also be taken for the meeting of the International Commission on Reinforced Concrete, over which Prof. F. Schüle, of Zurich, will preside, and on which the following British members will sit, namely:—Mr. Edwin O. Sachs, F.R.S.Ed. (Chairman, British Fire Prevention Committee); Mr. Wm. Dunn, F.R.I.B.A. (Chairman, Science Committee of the Concrete Institute); Mr. Max Clarke, F.R.I.B.A. (Member of the Council of the Royal Institute of British Architects); and Professor Unwin, LL.D. (Member of the Reinforced Concrete Committee of the Institution of Civil Engineers).

We understand that an important communication from the Science Committee of the Concrete Institute on the question of uniform algebraical notation will be before the Commission. Further, there will be a number of reports before the Commission on the tests undertaken on reinforced concrete in Europe, which reports should serve as a basis for determining the tests still required and the lines on which they should be conducted. It is to be hoped that the International Commission will make arrangements to meet at shorter intervals than heretofore, as their work should be of considerable immediate importance in both hemispheres.

NOTABLE CONGRESS PAPERS.

Amongst the papers to be presented at the Congress bearing on concrete and reinforced concrete are the following:—

An Official Report on the Work of the International Commission on Reinforced Concrete, by Prof. F. Schüle, Zurich.

Experimental Tests on actual Buildings, by Ch. Rabut, Versailles.

On Failures in connection with Reinforced Concrete Structures, by Dr. F. v. Emperger, Vienna.

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On Disturbances in the Bond Between Different Materials, by Dr. A. Leon, Vienna.

Contribution to Methods of Investigation into the Elastic Longitudinal Deformation of Concrete, by Dr. B. v. Bresztowsky, Budapesth.

Influence of Repeated Strains on the Bond between Concrete and Iron with Clean and with Corroded Surface, by Prof. B. Kirsch, Vienna.

The Influence of Thin Transverse Connections on the Strength of Concrete, by W. Nekrassow, St. Petersburg.

Experiments with Reinforced Concrete in Sea Water, by Prof. M. Möller, Brunswick.

AMENDMENTS TO THE LONDON BUILDING ACT.

THE amendments of the London Building Act, which have been before Parliament under the London County Council General Powers Bill, have now been finally reviewed by committees of the House of Commons and the House of Lords respectively, and it may be assumed that the original Bill with some slight modifications will shortly be placed upon the Statute Book. Thus, the metropolis should soon have the long-desired improvements in its building enactments, and a material development in the use of constructional methods may be expected within the county area.

The primary amendment which deals with steel frame buildings makes it lawful, under certain conditions, to erect structures entirely of steel frame without the absurd restriction of constructing the external walls—as heretofore—in such a manner as if they carried the weight of the floors, regardless of the fact that these loads are borne by stanchions. Another important amendment at last gives power to the London County Council to make regulations in respect to the use of reinforced concrete.

STEEL FRAME UNDER THE NEW AMENDMENTS.

Regarding the steel frame construction, the suggestion for the enactments might be said to have originated in certain requests of the Royal Institute of British Architects some four or five years back, when a special Building Act Amendment Bill was before Parliament. Remodelled in some respects and certainly improved upon, these proposals were embodied in the Bill now under discussion, but, for reasons scarcely explainable in print, the proposals as there put forward were most energetically combated on behalf of that self-same institution with whom the original idea had emanated. Much of this opposition, it is true, may be attributed to the fact that Mr. Riley, the Superintendent Architect of the L.C.C.—who had advised his employers in respect to this Bill—considered it absolutely necessary that in steel frame structures there should be efficient control over the interior of the structure by detailed enactment, where for ordinary structures matters are at present left very much to the discretion of the district surveyor. This question of "internal control" was, indeed, one open to technical discussion. We must protest, however, most strongly against the manner in which certain of the representatives of the Royal Institute not only combated the proposals but organised opposition in various directions The whole process of the opposition was anything but professional or dignified, and we believe that Parliament, in granting the proposed measures very much on the lines as originally drafted, did not attach quite the weight generally accorded to the opinions of opponents owing to the fact that the opposition was of the character described.

Mr. Riley is to be congratulated on the successful outcome of his proposals,

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for, with one notable exception—a concession in the matter of appeal which he was well advised to give way on—he has for all practical purposes obtained all the powers he desired to see vested in the London County Council.

It is not our intention at the present stage, before the measure is on the Statute Book, to refer in any detail to the new code except to state that, from the fire point of view, we are glad to see the compulsory enclosing of all steel framing, and that we note with pleasure that where Portland cement is required its quality must conform to that set out in the British Standard Specification.

REINFORCED CONCRETE UNDER THE NEW AMENDMENTS.

As far as reinforced concrete is concerned, we fear that the position accorded to it before the House of Commons was a very secondary one, due probably to the fact that some of the advocates of that material were primarily occupied in the steel frame controversy. Originally, it was intended that the London County Council should have power to make regulations, and the decision of the Council was to be accepted as final as to their character. The only point achieved now is that these regulations have also to meet with the approval of the Local Government Board, which will probably mean a far more severe standard being set than the Council would have required. Notice of any proposed regulations has to be given to the various technical societies, amongst them we are happy to note, is the Concrete Institute; thus these bodies will no doubt have a hearing before the Local Government Board But we are afraid that these slight changes as to notices, etc., from the original proposal have only an academic and paper value, and to our mind it would have been wiser if those interested in reinforced concrete had accepted the Bill as originally drafted. Whatever may be said to the contrary by parties who have grievances, the London County Council has—during the last ten years—taken a very equitable view of matters relating to building construction, and those concerned in reinforced concrete would have done better to have left themselves in the Council's hands than have left the approval of the regulations to the Local Government Board as at present officered.

In spite, however, of these matters of procedure, the Building Act Amendments, as a whole, are a move in the right direction, and should eventually materially facilitate building on up-to-date lines in London, and if the new code does not provide for everything that might have been desirable, it should, nevertheless, be most welcome to builders and contractors, to building owners and to their technical advisers.

REINFORCED CONCRETE BRIDGE IN IRELAND.

In our last issue we referred to the controversy as to the re-erection of the bridge over the River Suir, at Waterford, Ireland. It will be remembered that after the Waterford Corporation had provisionally decided to rebuild the bridge in reinforced concrete, tongues were set wagging as to the non-suitability of that method of construction, with the result that the Corporation appealed to the Privy Council asking them to revoke their earlier decision with regard to the adoption of reinforced concrete and to recommend instead that the bridge be erected entirely of steel. Evidence was heard in support of that contention, but in the end the commissioners decided in favour of reinforced concrete, and asked that plans and specifications be supplied as soon as possible.

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These have been furnished, and the Schedule of Amendments have now been issued by the Privy Council with reference to the construction of the bridge in reinforced concrete. They comprise in all thirteen clauses, of which some, however, only deal with the proposed structure in a general manner, whilst the majority have special bearing upon the application of reinforced concrete.

We give below, in full, those clauses which directly concern reinforced concrete, as they are no doubt of technical interest.

"The specification and plans should set out clearly the depth to which the foundation piles are to be driven, and in the clause dealing with pile driving, 4 ft. should be substituted for 2 ft. as the height of drop.

"The cylinders encasing the piles should be sunk to a depth of at least 6 ft. into the river bed in the case of the ordinary piers and at least 10 ft. at the opening span. The specification should further provide for the removal of the mud inside the cylinders around the piles.

"The floor of the bridge should be made water-tight by a layer of asphalte or asphaltic material covering the entire area. The specification requires amplification as to the construction of the roadway and footpaths and provision for the drainage thereof.

"The minimum thickness of concrete covering the steel reinforcement, in any part of the structure, should be at least 1½ in.

"It should be stated clearly whether fresh water is to be used for the concrete, and, if so, how it may be obtained.

"The period of six months proposed for maintenance by the contractor, after completion, is inadequate. The contract should provide that the contractor shall maintain the whole structure in perfect condition to the satisfaction of the engineer of the Joint Committee for two years after its completion has been duly certified, without any charge for such assistance.

"The contractor should be bound, at the option of the Committee, to be exercised at least two months before the expiry of the period of two years of free maintenance, to maintain the whole structure in perfect order to the satisfaction of the engineer, for a further period of four years, in consideration of a payment to him for such maintenance of a definite amount per annum set out in his tender. Such maintenance should extend to all parts of the structure, appliances and machinery, including the roadways and footpaths, and the painting of all exposed ironwork in the third and sixth year of maintenance.

"The specification, it is observed, is based on quantities supplied by Messrs. Mouchel & Partners. The contract for the work should not embody any schedule of quantities, but should recite that the contractor has satisfied himself as to everything required for the proper completion of the bridge, and undertakes to erect it for a definite sum.

"There is a provision in the specification to the effect that the works shall be in conformity with the specification and drawings signed by the engineer of the Joint Committee of the City of Waterford, and the contributing counties, Messrs. Mouchel & Partners, and the Committee, respectively, according to their directions and subject to their control and approval; and any doubt, etc., etc., etc., should be referred to their decision, which shall be final. Objection has been taken to this provision on the grounds that the contractors for 'ferro-concrete' constructions on the Hennebique system are owned, controlled, and employed by Messrs. Mouchel & Partners, one of whom, J. S. de Vesian, is the engineer, whose plans have been accepted. The standard specification for 'ferro-concrete' of Messrs. Mouchel & Partners provides as follows: In order to provide for the satisfactory and efficient performance of these works, no tender shall be received except from such contracting firms as are authorised to execute ferro-concrete constructions on the Hennebique or other systems owned, controlled, or employed by Messrs. Mouchel and Partners, and who shall be employed by the contractor as his engineers and technical advisers in all matters connected with or arising out of these 'ferro-concrete' works. This provision is doubtless a satisfactory business arrangement for ensuring that Messrs. Mouchel's detailed directions shall be carried out in the application of their patented methods, but having regard to it as evidence of the usual relations between them and the contractors executing works involving their system of construction the proposal in this case that they should act as engineers to the contractors, and at the same time as joint engineers on behalf of the contributing areas, appears to be open to objection. This provision should be altered in the specification, so that the terms of the Bridges Act may be complied with. Under this Act it is provided that the work must be carried out to the satisfaction of the Joint Committee and the County Surveyor appointed by them to assist in the superintendence of the works."

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REINFORCED CONCRETE AT THE NATIONAL GALLERY.

The reinforced concrete work at the National Gallery is of more than ordinary importance, not only from a technical point of view, but as an instance in which the new material is being applied to Government buildings.—ED.

REINFORCED concrete construction is rapidly gaining favour with the Office of Works, and the latest employment of that method of construction is to be found in the extensions to the National Gallery, Trafalgar Square, London. The reinforced concrete work on these extensions has been carried out on the Kahn system by Messrs. W. Moss & Sons, to the general directions of the principal architect, Sir Henry Tanner, I.S.O., F.R.I.B.A., Mr. H. N. Hawks, I.S.O., acting as architect in charge of the work. The reinforced concrete to these extensions consists of columns, floors, and the roof.

In plan, the extension is roughly in the form of a letter T, the two extremities of which letter are two long galleries, one 40 ft. wide and the other 32 ft. wide. Over the centre of the latter gallery a dome is constructed, as shown in *Fig.* 5.

From the drawings (*Figs.* 2, 3, 4) it will be seen that the roof principals are of the arched type, similar to those adopted in the Hammersmith Baths, which we dealt with in our March, 1908, issue. They act as girders, and no tie-bars are used across the building. The whole of the stress due to the thrust of the arch is taken up in the beam itself, the greatest stress being at the crown, which is the deepest part of the principals. These principals carry ventilating chambers in reinforced concrete in addition to the roofing, the chambers housing the blinds. The span over the roof of the West Gallery is 40 ft., while that of the Northern Gallery is 32 ft., the principals being respectively 6 ft. 8 in. deep by 14 in. wide at the crown and 5 ft. 2 in. by 14 in. wide.

Figs. 5 to 11 show different portions of the roof which are self-explanatory. The rectangular shaped openings in the elevations of the lantern are for ventilation.

The construction of the dome shows many interesting features that will be seen from the illustrations (*Fig.* 5), and the method of construction is shown therein. It will be seen that the top of the ribs runs against a reinforced concrete ring which takes the thrust, whereas the thrust of the lower portions of the principals is taken by rods which form a ring around the dome. Another

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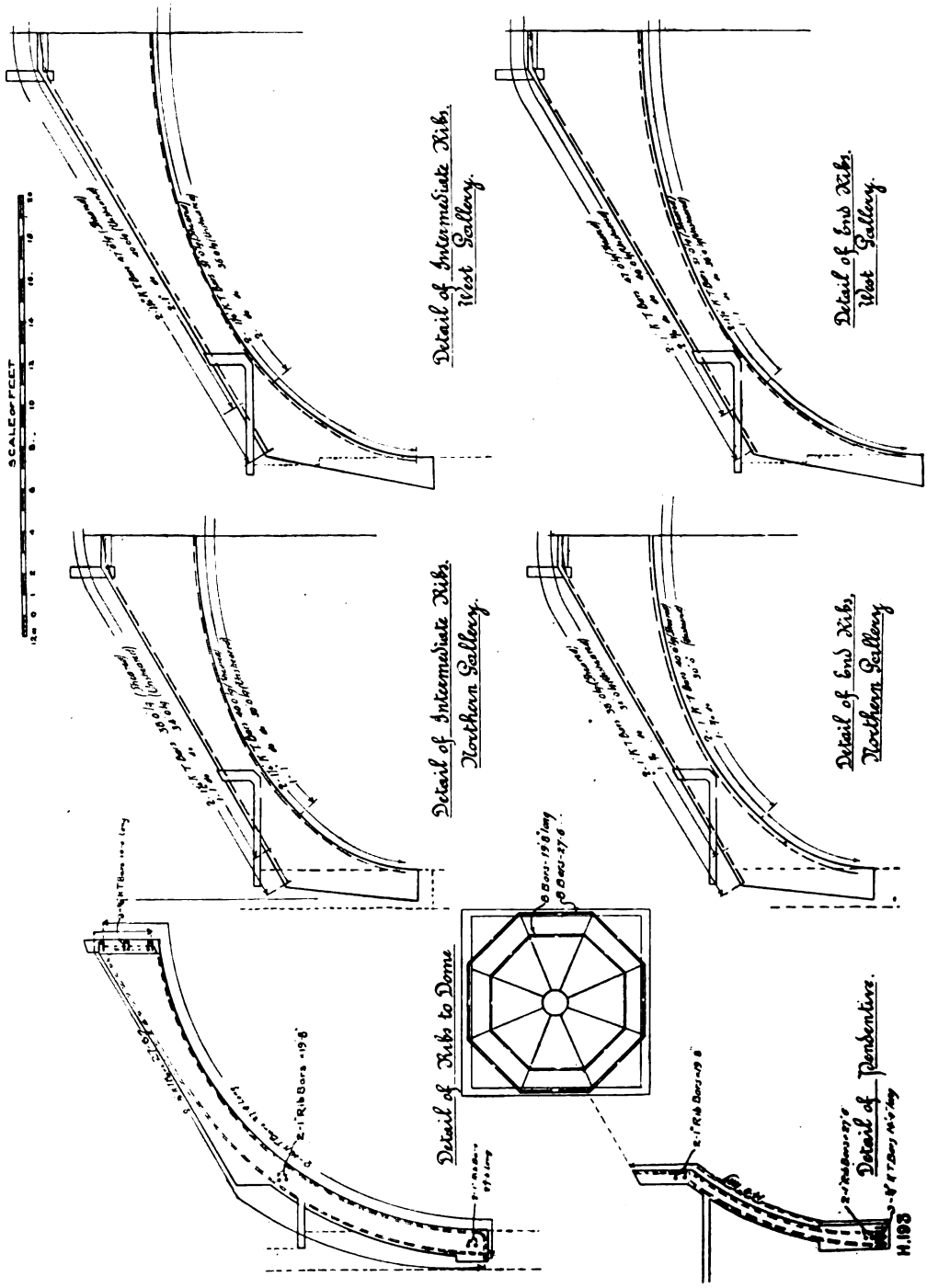

FIG. 2. REINFORCED CONCRETE AT THE NATIONAL GALLERY: Details of Roof.

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ring of rods placed nearly halfway up the arched ribs prevent the spread of the principals at that part. Some portion of the way up the dome a flat runs round outside, and between the flat to the ring at the crown the dome is glazed between the principals. The dome is of 32-ft. span, and its full height above the floor is 34 ft. 6 in. Supported on four reinforced beams, 1 ft. 1 in. by 3 ft. 3 in., are eight smaller beams, 8 in. by 1 ft. 9 in., from which spring the hips supporting the turret and forming the roof. These hips are reduced from 12 in. in thickness to 8 in. where the circular ring, the underpart of the turret, is met. This concrete ring is 8 in. in thickness and 3 ft. 3 in. in height, with 1 ft. 9 in. as its internal diameter. Above this ring is an octagonal cill, 8 in. by 8 in., on which are mullions of the

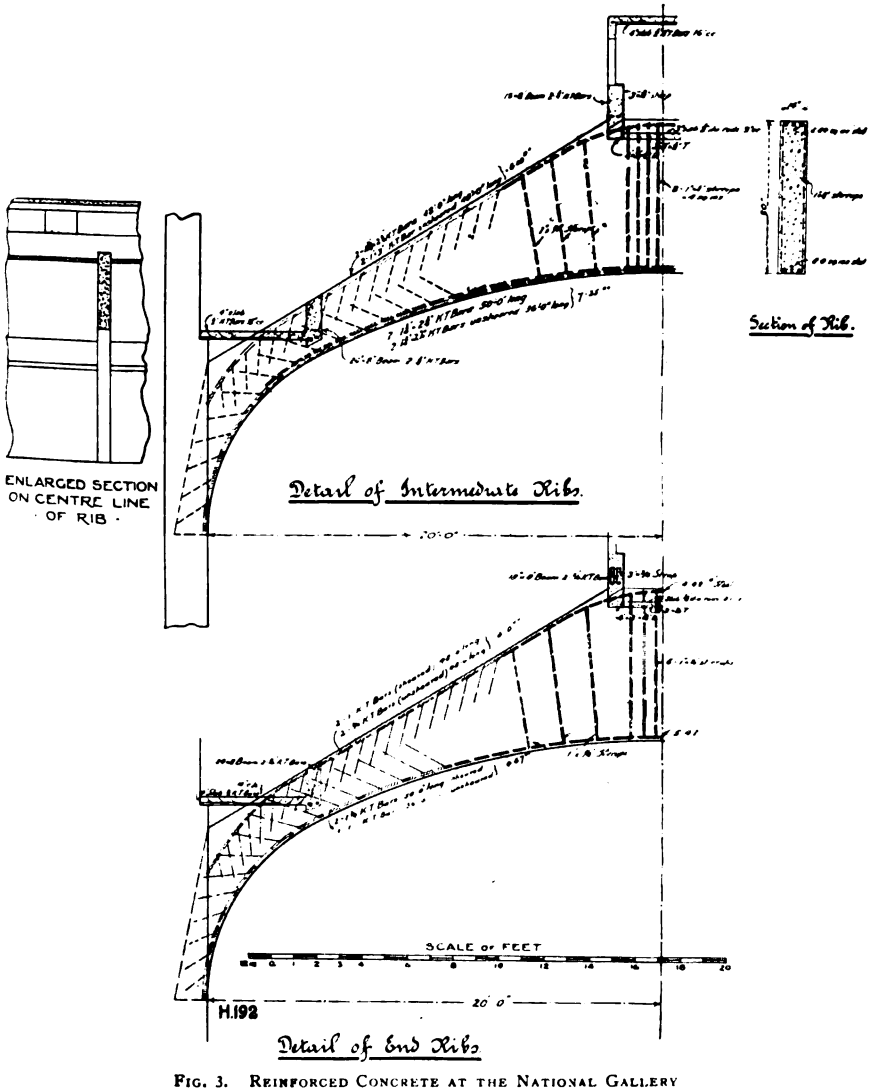

FIG. 3. REINFORCED CONCRETE AT THE NATIONAL GALLERY
Calculations and Details of 40-ft. Rib Span—West Gallery.

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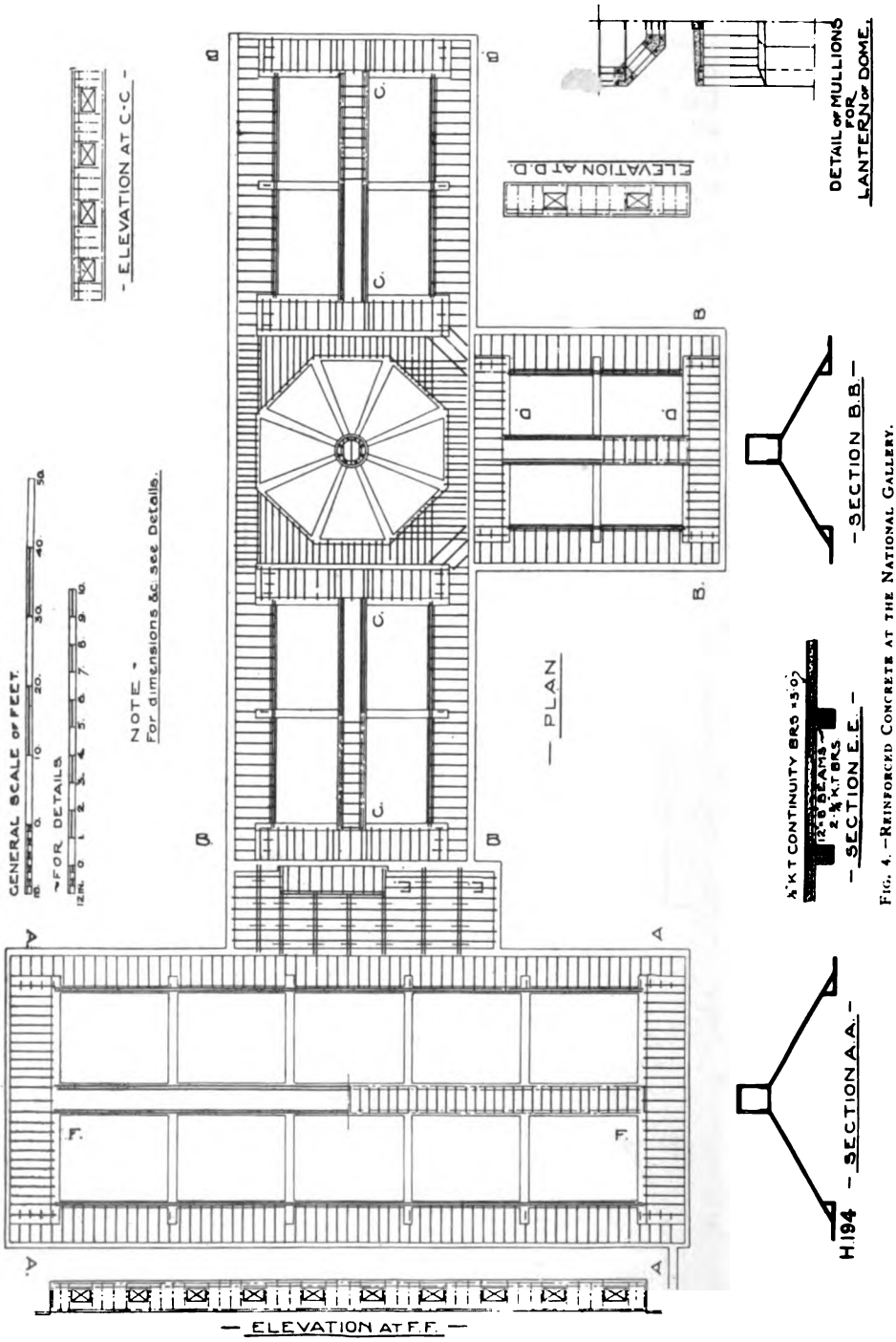

FIG. 4.—REINFORCED CONCRETE AT THE NATIONAL GALLERY.
Plan of Roof.

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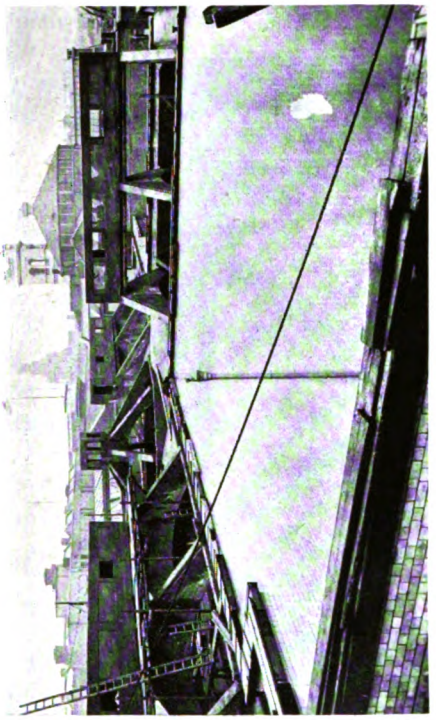
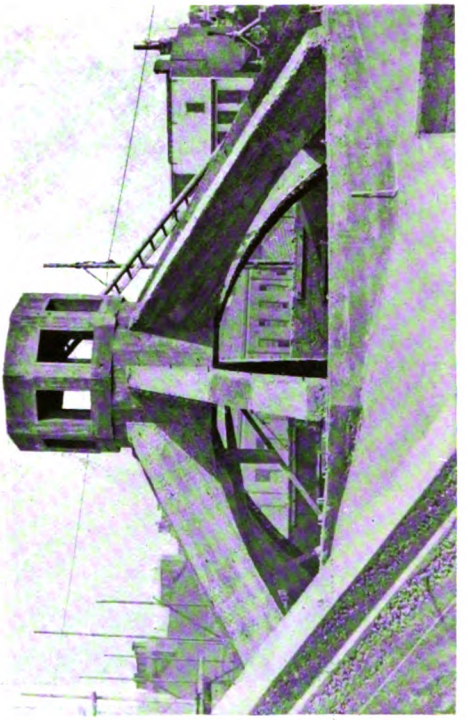
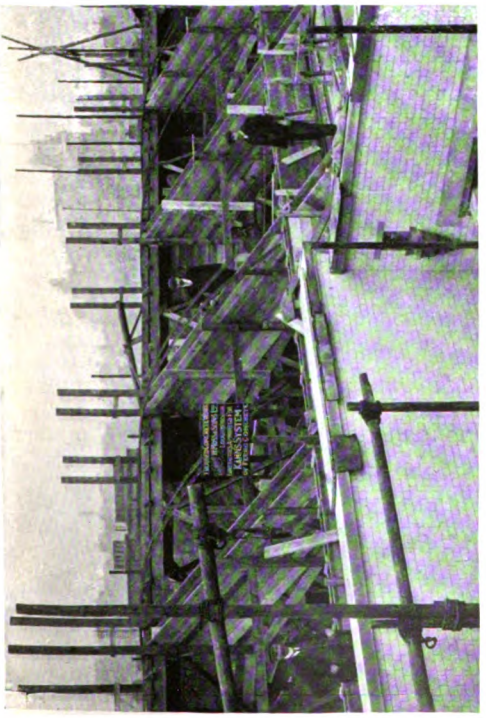


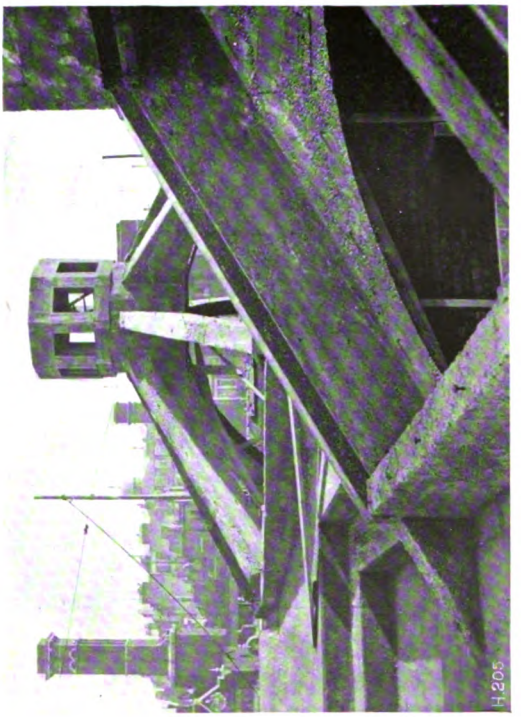
Showing the framework for one of the ventilating galleries; also another ventilating gallery and the ribs supporting it completed.



Reinforced Concrete Dome Roof.



Reinforced Concrete Dome Roof showing in the foreground part of the roof of one of the smaller ventilating galleries.



FIGS. 5 TO 8. REINFORCED CONCRETE AT THE NATIONAL GALLERY.

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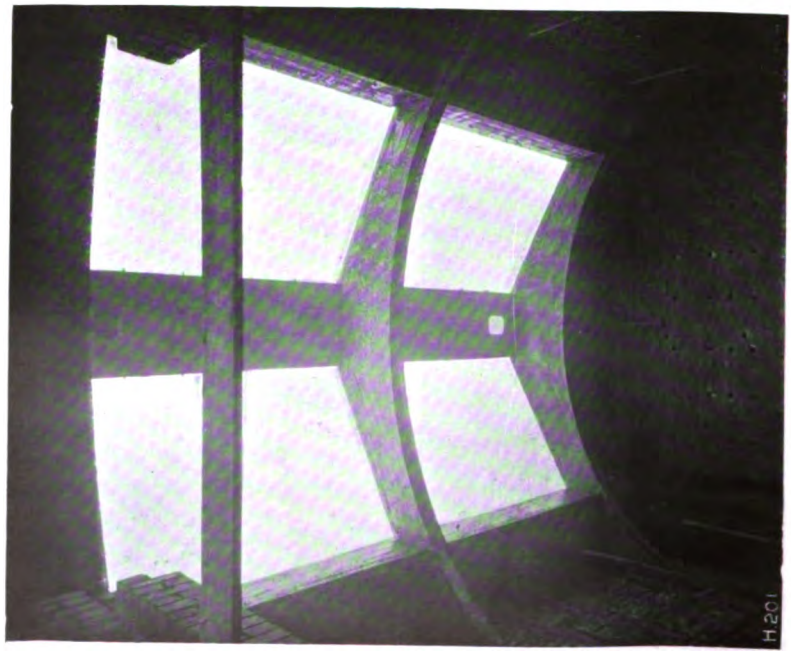

FIGS 9 and 10. REINFORCED CONCRETE AT THE NATIONAL GALLERY.
Showing openings for ventilation.

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same thickness and 1 ft. 9 in. in height, supporting a head 8 in. thick. Above this is a 4 in. cover. Flats on the sides of the roofs are also shown over the other galleries, and above these flats glass runs between the principals as in the case of the dome.

Bolts have been left in the concrete to enable grounds for fibrous plaster and blind fittings to be fixed. Rebates have also been left, steps made on the drum, and gutters formed.

The centering to the longest roof is remarkable for its economical construction. Its efficiency depended largely upon the careful and skilful manner in which it was erected.

The columns and floors are constructed on the lines customary where the Kahn system is applied. The beams carrying the first floor, however, are made of hollow form, and contain ventilating air-ducts 20 ft. by 12 ft. Kahn trussed bars have been used throughout.

We understand that the East Wing of the National Gallery is shortly to be reconstructed, reinforced concrete also being applied to this improvement.

FIG. 11. REINFORCED CONCRETE AT THE NATIONAL GALLERY.
(View during construction.)

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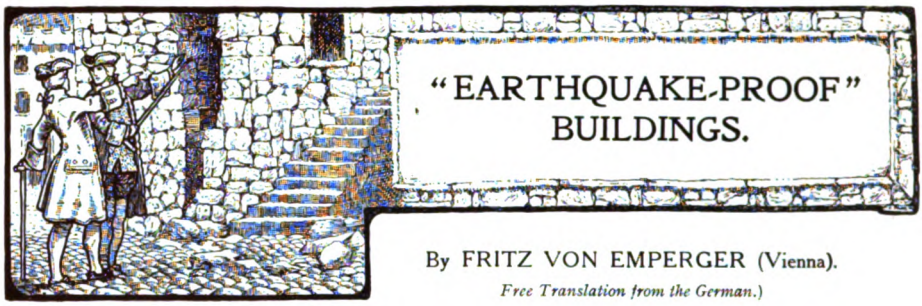

"EARTHQUAKE-PROOF" BUILDINGS.

By FRITZ VON EMPERGER (Vienna).

Free Translation from the German.)

The necessity of meeting the risk of earthquake shock in many districts has led numerous authorities to investigate the possibilities of protecting buildings in such a manner as to assure the safety of inmates, as far as it is possible under present conditions, and in those investigations there has been a considerable leaning towards the application of reinforced concrete to what may be termed "earthquake-proof" buildings. An eminent authority on the subject is the Editor of our contemporary, "Beton u. Eisen," Prof. Fritz von Emperger, and it affords us great pleasure to present his views in summary, as expressed in his journal this year and recently issued as a reprint by Messrs. Ernst & Sohn, of Berlin.—ED.

Method of Construction.—The difficult problem of constructing buildings capable of resisting earthquake shocks in districts subject to them has received many attempted solutions on the part of inventors, often consisting in elaborate mechanical arrangements for isolating the building from the movements of the earth on which it rests. Apart from the fact that such mechanisms are difficult to keep in order, experience shows that the building should be connected as rigidly as possible with its foundation, and that the aim should be rather to construct a framework capable of resisting horizontal thrusts in any direction in the same way that an ordinary structure is designed to resist vertical loading. Supporting on separate feet or pillars may result in the whole load being thrown momentarily on a single support in the course of the rocking movements set up by an earthquake, especially when interfering systems of waves are produced, as is often the case. A light, rigid skeleton, firmly connected with its foundation, is the most satisfactory arrangement. It is impossible to construct a building which will be proof against the extraordinarily violent shocks which occur in great catastrophes, but the shocks which usually occur in regions subject to earthquakes may certainly be resisted. The matter is simplified if the prevailing direction of the earthquake waves is known.

Material for Construction.—Reinforced concrete is an eminently suitable material for the construction of the skeleton, having the necessary lightness and qualities of fire resistance, whilst providing a ready means of making the whole skeleton a statical whole by its monolithic character. The most rigid form to be given to the skeleton is theoretically that of a paraboloid of revolution, but the practical requirements of habitable dwellings necessarily limit the choice of the designer to rectangular forms. The simple cage-like skeletons shown in *Fig.* 1. are the most practicable form, the vertical and horizontal ribs being thoroughly tied together; whilst the walls consist of thin reinforced concrete panels, lined with a non-conductive composition. Stairs are built up of a reinforced concrete framework with hard wood treads, and the floors preferably of reinforced concrete panels with a diagonal stiffening and a wood block floor covering.

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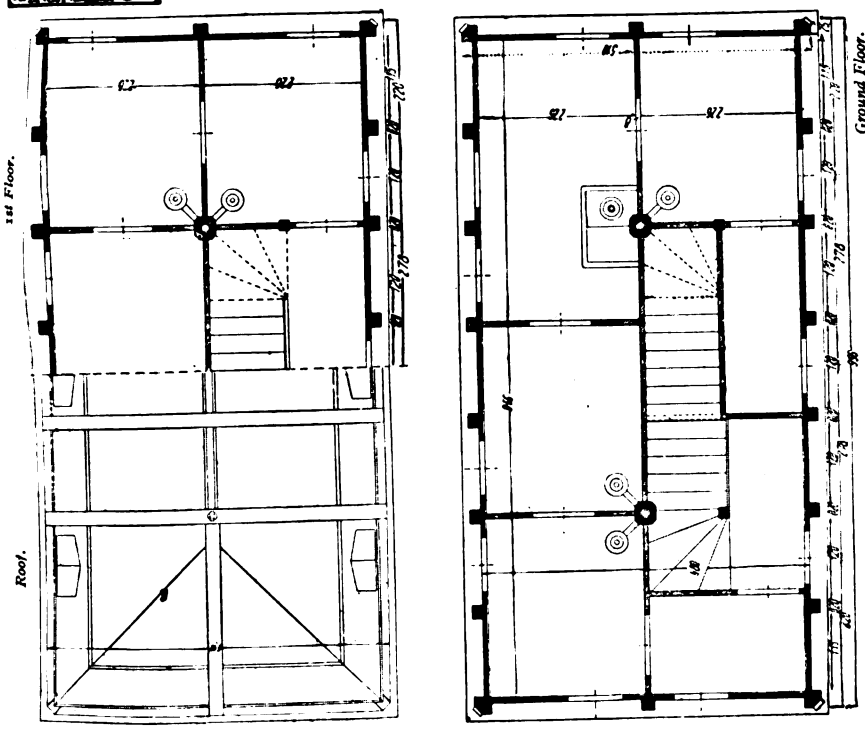

FIG. 2. PLANS OF A MODEL REINFORCED CONCRETE "EARTHQUAKE-PROOF" BUILDING.

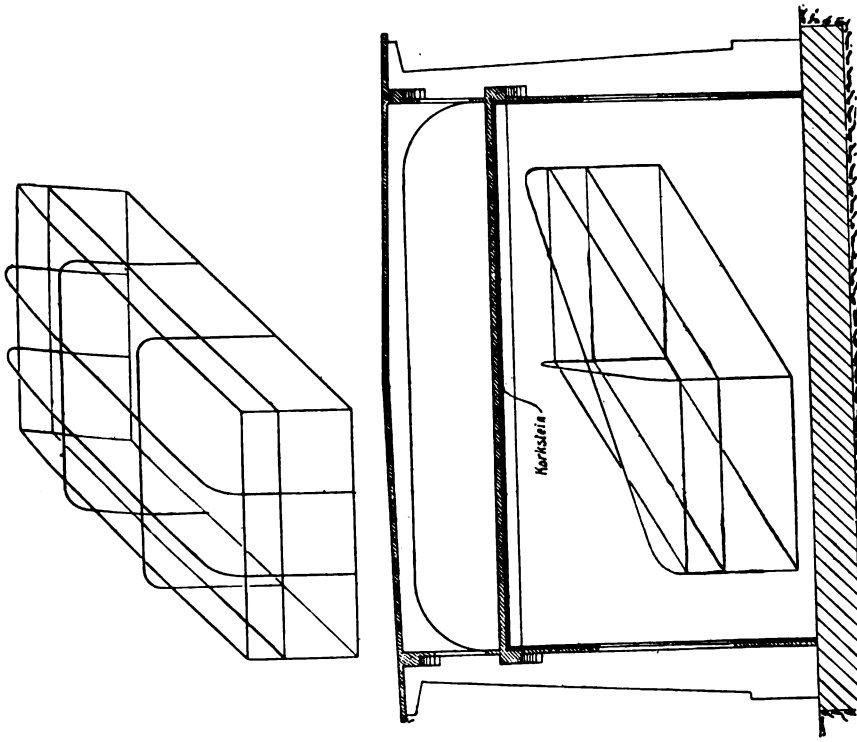

FIG. 1. DIAGRAMS INDICATING A SIMPLE REINFORCED CONCRETE "EARTHQUAKE-PROOF" FRAMING.

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Some Experiments.—Experiments by Omori in Japan, who subjected vertical brick pillars to rapid horizontal movements at the base, showed that in such cases fracture always takes place near the junction with the ground. This is, however, not the case with actual buildings, the strength of which is not uniform throughout their height, but diminishes upwards. Experience in Japan shows that destruction in such cases takes place at the junction of the roof with the walls, or at a point in an upper floor—that is, at the point least able to resist horizontal thrust.

New Form of Construction.—The author has devised a form of construction capable of resisting the shocks experienced in such a district as that of Calabria—that is, all shocks except the very rare catastrophic earthquakes. The maximum permissible height of a house in Calabria is 10 metres (33 ft.). The general mode of construction is shown in *Figs.* 2 and 3 (*dimensions in centimetres*). Frames crossing at right angles have been adopted, as sufficient strength can be secured by this means, and the difficulties of diagonal frames are avoided. The arrangement of the reinforcement is shown in *Figs.* 4 and 5. Each upright of the framework has four flat bars 50×6 mm. (2 in. × ¼ in.) anchored in the foundation by means of channel iron. There is no diminution in the dimensions of columns in the upper storeys. The walls are of 5 to 8 cm. (2 to 3¼ in.) concrete, reinforced with rods, the lining being 3 cm. (1¼ in.) thick. Windows are built in as shown in *Fig.* 4. The floors are necessarily light, and a rigid frame construction has been adopted throughout.

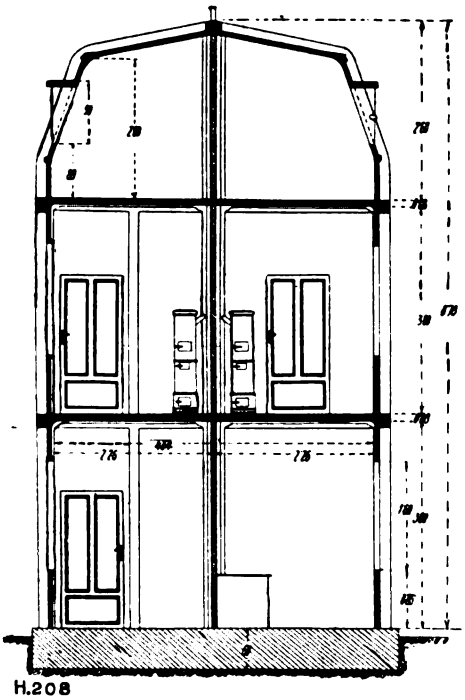

Fig. 3. Section of a Model Reinforced Concrete "Earthquake-Proof" Building.

Statical Computation. — The author adds a complete statical computation of the roof, on the basis of the elastic theory. The framing is rigidly connected both with the walls and the upper floor, making the whole construction monolithic. The calculation is a complicated one, owing to the fact that thrusts from all directions must be taken into account. The roof must have a degree of safety equal to that of the lower part of the building, since disasters have often occurred through the roof being displaced by the shock, and falling in and crushing the lower part. The general arrangement is that of a cage, made up of a series of frames. The filling may be either like that of the walls, reinforced concrete panels with lining, or it may consist, as in *Fig.* 6, of wooden laths with inner and outer covering of slabs. The

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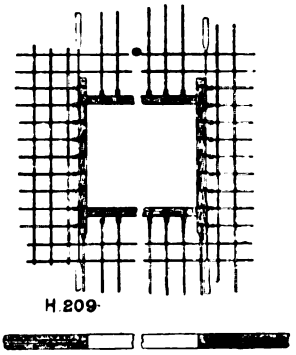

FIG. 4. WINDOW AND DETAIL OF WALL.

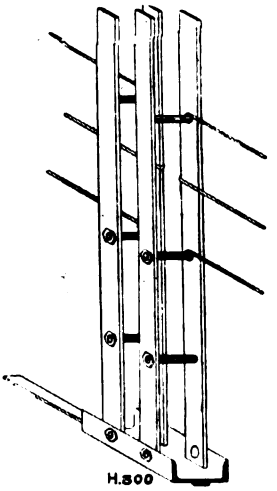

FIG. 5. DETAIL OF UPRIGHT

chimneys are of terra-cotta, built against one or more of the columns. The cost of such a building, exclusive of foundations, windows, etc., may be taken at 50 per cent. in excess of that of an ordinary dwelling house of the same size.

Conclusion.—The author further examines the resistance to earthquake of different types of structure, and concludes by emphasising that in any case a form of frame construction should always be adopted for high buildings in districts subject to shock.

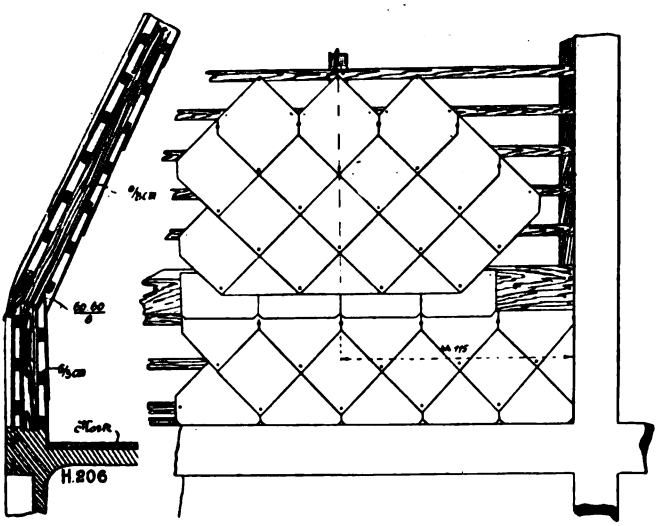

FIG 6. SUGGESTION FOR A SLAB ROOFING.

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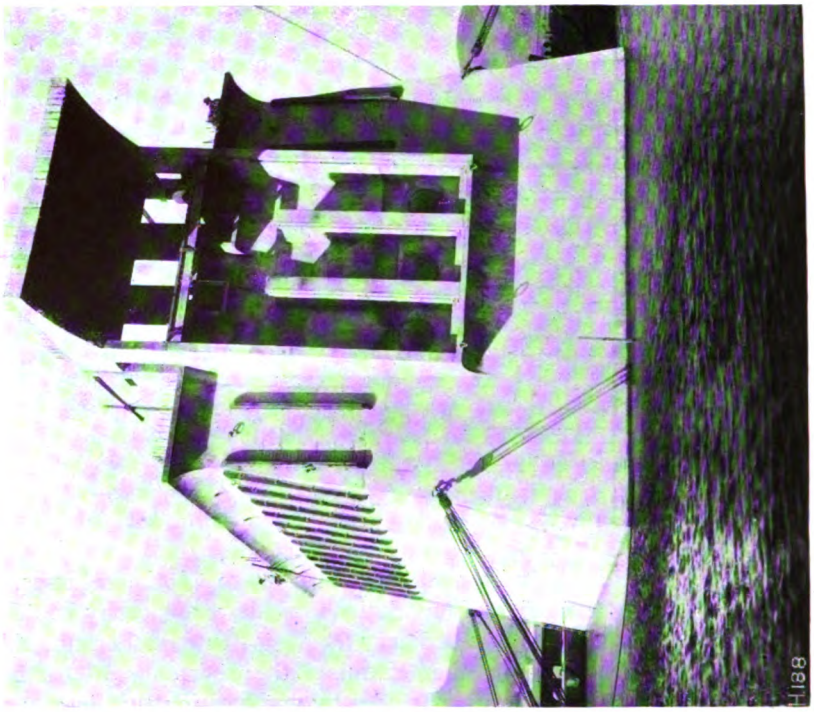

FIG. 2. THE REINFORCED CONCRETE CAISSON FLOATED IN DOCK.

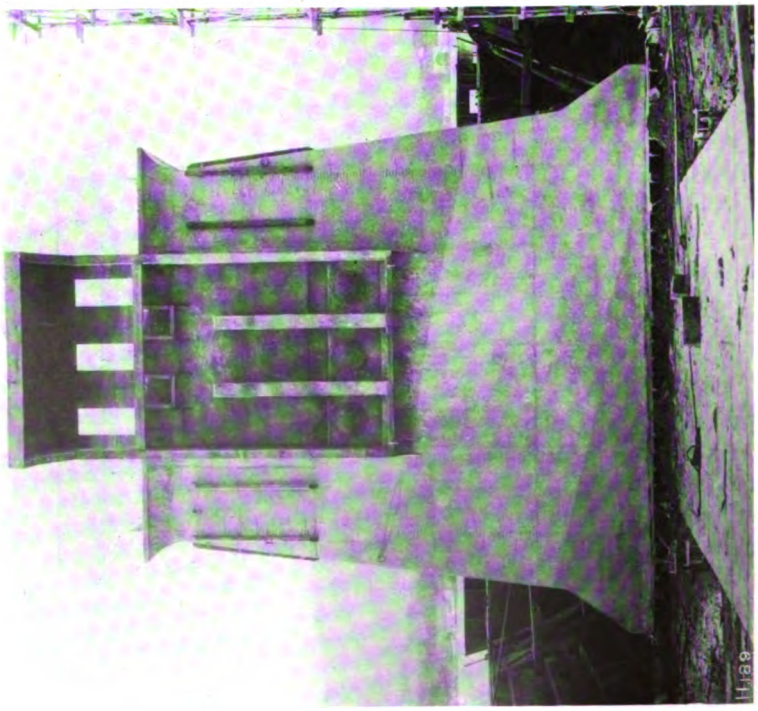

FIG. 1. THE REINFORCED CONCRETE CAISSON READY FOR FLOATING.

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FIG. 4. THE CAISSON MOORED.

Reinforced Concrete Torpedo Station in the Mediterranean

The extraordinary and useful purposes to which reinforced concrete is being put in France may be gauged from the particulars and illustrations presented herewith by the courtesy of "Le Béton Armé," of a large caisson of that material. Not only is the purpose to which the material has been applied of interest, but the manner in which the intention of the designers has been achieved by floating the structure into position, as the caisson was of considerable dimensions.—ED.

Introduction.—The well-known manufacturers of ordnance material, Messrs. Schneider & Co., of Creusot, having taken up the manufacture of torpedoes, recently found it necessary to establish a station, with a suitable area of water of fairly uniform depth, for the purpose of torpedo trials. As a suitable site could not be found on the coast, it was resolved to construct the station in the sea at some distance from land, and a position was found in the roads of Hyères, in the Mediterranean. It was at first proposed to construct a large coffer-dam, and to erect the necessary buildings within it, but such a dam was found to present many constructional difficulties. Ultimately a proposal of their chief engineer for civil engineering works, M. Michel-Schmidt, was adopted, dispensing with the dam and replacing it by a large reinforced concrete caisson, to be built on shore and floated to its place. The Hennebique system of design was applied and the Société Générale des Constructions en Béton Armé acted as contractors.

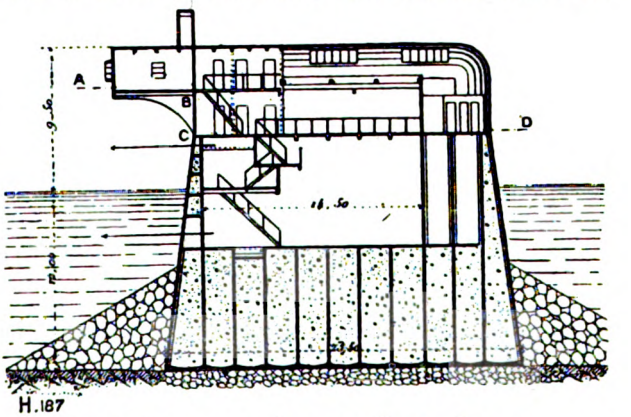

FIG. 5. DIAGRAMMATIC SECTION OF TORPEDO STATION.

Dimensions. — The structure consists, as our illustrations show, of a large caisson, 23·5 metres (77 ft. 3 in.) long, 16·8 m. (55 ft. 2 in.) wide, and 15·5 m. (51 ft.) high. The building above the caisson is 6 m. (19 ft. 8 in.) high, and has a

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projecting portion overhanging one end by 5·5 m. (18 ft.), containing the observation room. A small light-tower surmounts this portion of the structure. The room for experiments with torpedoes discharged under water is in the caisson itself, whilst the superstructure is used for tests with torpedoes discharged above the water-line.

Construction.—The construction of the caisson began in March, 1908, in one of the dry docks of the shipbuilding yards of La Seyne, near Toulon. *Fig.* 1 represents the caisson ready for floating. On August 23rd, water being admitted to the dock, the caisson floated, with the calculated draught of 3·3 m. (10 ft. 10 in.). (See *Fig.* 2.) The floating structure was then towed into the Toulon roads by two tugs (see *frontispiece and Fig.* 4) and anchored to a buoy, in order that the internal concrete work might be completed. This included the erection of the partitions shown in the section (*Fig.* 5). Sufficient concrete was then filled into the compartments to increase the draught to 8 m. (26 ft. 4 in.), this being necessary to ensure stability during the operation of towing out to sea. On November 5th the caisson was taken in tow by two tugs and removed to its destination, a distance of 25 miles, in rough weather.

Fixing the Caisson.—A rock platform had been prepared and levelled for its reception by divers, at a depth of 12 m. (39 ft. 5 in.), and the caisson was placed in position above this. Water was then pumped into the interior compartments until the caisson sank and rested securely on its bed. The form of the caisson, tapering upwards, is well suited to resist wave-pressures, but in calculating the dimensions, a wave-pressure of 20,000 kilog. per sq. metre (1·8 tons per sq. ft.) was assumed. The central compartments were next filled with sand and the outer with concrete. This arrangement makes it possible to remove the caisson at any future time, should this be necessary, all that would be needed being to remove the loose ballast from the central compartments, which would lighten the structure sufficiently to cause flotation

The general appearance of the completed structure is seen from a rough sketch reproduced in *Fig.* 6.

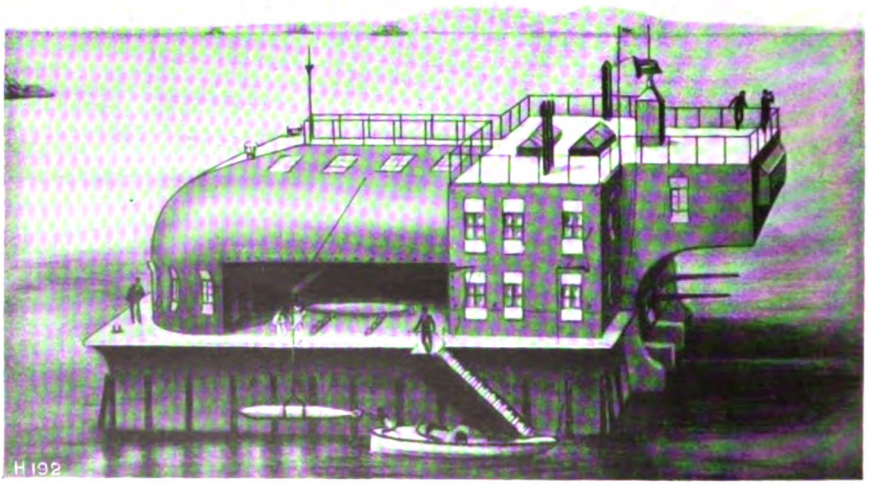

FIG. 6. THE COMPLETED STRUCTURE.
(Sketch showing torpedo station in operation.)

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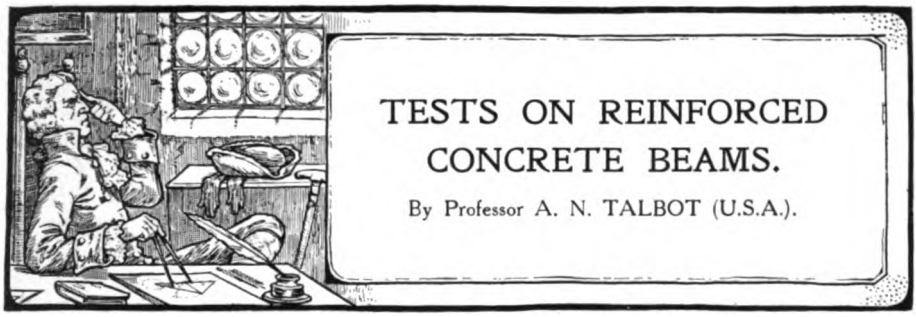

TESTS ON REINFORCED CONCRETE BEAMS.

By Professor A. N. TALBOT (U.S.A.).

We have from time to time presented summaries of the important data collected in investigation and test by Prof. A. N. Talbot, of the University of Illinois, U.S.A. In this issue we are presenting a further series of most important facts issued by that eminent authority in one of his University Bulletins. The importance of the tests is such that we would have been pleased to have presented it in extenso, but it comprises some 80 pages, and we, therefore, content ourselves with a summary which has been prepared for us by Mr. C. H. Desch, D.Sc., Ph.D., of the Glasgow University.—ED.

Introduction.—In continuation of the important series of researches conducted by Professor A. N. Talbot, of the University of Illinois, U.S.A., several of which have been described in CONCRETE, experiments have been made to determine the resistence to web stresses of different types of reinforced concrete beams. In spite of the extensive character of the programme (188 beams were tested in 1907-1908) Professor Talbot does not consider that the data obtained are sufficiently numerous and comprehensive to admit of any broad generalisations. Nevertheless, the results are of high importance, and add greatly to our knowledge of web stresses, the theoretical treatment of which lags far behind that of the simpler tensile and comprehensive stresses.

Designation of Tests.—The tests were designed to give information as to the effect on the resistance of web stresses of (1) the mode of reinforcement (2) the richness

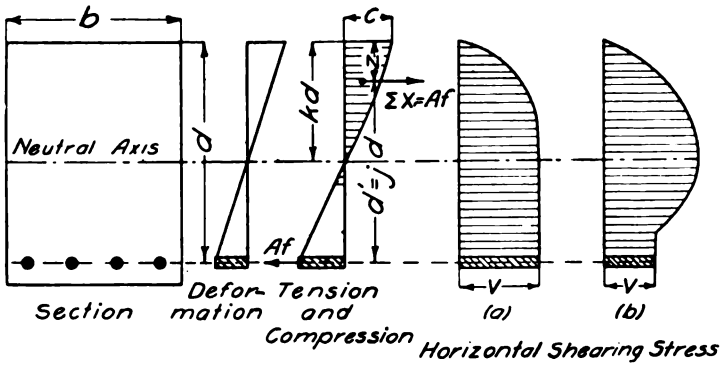

FIG. 1. DISTRIBUTION OF STRESSES OVER CROSS-SECTION OF BEAM.

of the concrete mixture, and (3) the age of the concrete. The beams were of large size, all being 8 in. × 11 in. section, the length varying from 6 ft. to 12 ft. The concrete was made with crushed limestone, sharp, graded sand and cement mixed by hand. As reinforcing material round rods of mild steel, square corrugated rods, some of mild steel and others of a harder steel, and a form of built-up reinforcement, known as Cumming's unit frame, were used, as well as two beams with expanded metal in the web. Control tests were made with 6-in. cubes and with small beams

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40 × 6 × 8 in., without reinforcement, for bending. The load was applied to the larger beams, with two exceptions, at two points, dividing the span equally into three parts.

Nature of Stresses.—The web stresses are made up of shearing stresses in various directions, tensile and compressive stresses in directions other than that parallel to the axis of the beam and bond stress, or resistance to slip between steel and concrete. The calculation of these is only approximately possible. The bond stress in a beam reinforced only with straight rods is $u = V/ mod'$, where V is the total vertical shear at the given section, m the number of bars, and o the periphery of each bar, and d' the distance from the centre of the rod to the centre of compression in the concrete. The horizontal (and also the vertical) shearing unit-stresses are given by the formula $v = V/ bd$, at a point just above the reinforcement. The distribution of stresses over a vertical cross-section is shown in *Fig.* 1. The diagonal tension is indeterminate, it probably varies from v to $2v$.

Manner of Failure.—Failure by diagonal tension occurs in beams without web reinforcement. A crack starts suddenly at the lower edge and runs diagonally away from the support, as shown in *Fig* 2. This form of failure is dangerous from its suddenness. It is most liable to occur in beams made with a poor concrete mixture. The stiffer the beam the larger the safe shearing stress, so that deep beams give higher results than slender ones. The conditions are greatly modified by the bending up of the reinforcing rods. The calculation of the resulting stresses is impossible, and it is probable that a plane cross-section does not remain plane on bending. The diagonal part of the bar takes a part of the diagonal tension, and failure may occur in one of several ways. The formation of a vertical crack between the point of bending and the support, followed by splitting of the concrete along the line of the diagonal rod, is characteristic of this type of beam (*Fig.* 3).

Straight Rods.—The use of some straight rods and others bent up leads to an indeterminate distribution of stresses (*Fig.* 4). Failure is much slower, and the web strength is good if the diagonals are properly spaced. A rigid connection between the main and diagonal reinforcing rods, as in the Cummings unit and the Kahn bar, gives good web strength. When vertical stirrups are used they take little stress until a diagonal crack has formed (*Fig.* 5). Even under the heaviest loads they do not take more than about two-thirds of the vertical shear. The nature of the bond developed is of great importance in this case, and this depends on the quality of the concrete.

Results of the Tests.—The different types of reinforcement are shown in *Fig.* 6. Beams without web reinforcement generally carried a load somewhat greater than that at which the first diagonal crack appeared, but sometimes the failure was sudden and complete. With a dead load failure would have been instantaneous. The vertical shearing strength increases with the richness of the concrete, varying from 180-200 lb. per sq. in. for a 1 : 1 : 2 mixture to 80-120 lb. per sq. in. for a 1 : 4 : 8 mixture in 6 ft. beams sixty days old. There is very little increase in strength after about forty days, but lean mixtures attain their strength more slowly. Tests with control beams without reinforcement show that the modulus of rupture of such beams tested by flexure is not far from twice the vertical shearing strength of a beam made of the same concrete and of the same age. The ratio of the compressive strength of 6-in. cubes to the shearing strength of beams is also fairly constant under similar conditions, being from 16 to 20. These ratios may be found valuable in the control of constructional work.

Shearing Strength.—The shearing strength also increases with the amount of longitudinal reinforcement, as the less strongly reinforced beams become more highly

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curved and the cracks develop nearer to the support. The reason is not the production of higher bond stresses, since deformed bars do not give higher stresses than plain bars. The shearing strength naturally falls with increasing ratio of length of the

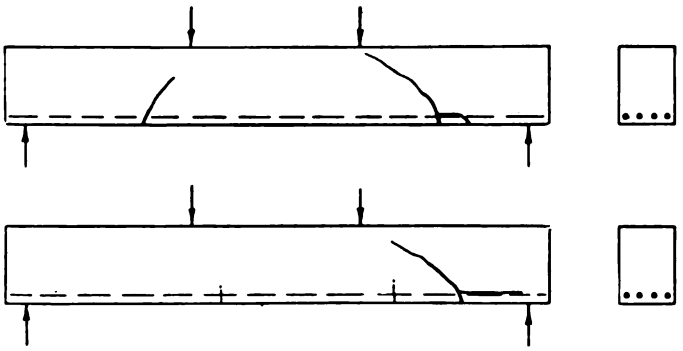

FIG. 2. POSITION OF CRACKS IN DIAGONAL TENSION FAILURES

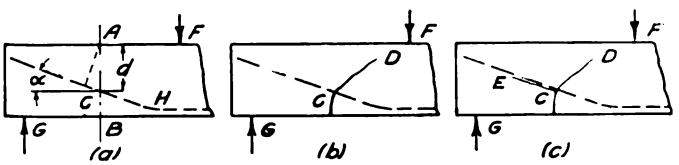

FIG. 3. DIAGONAL TENSION FAILURE IN BEAMS, ALL BARS BENT UP.

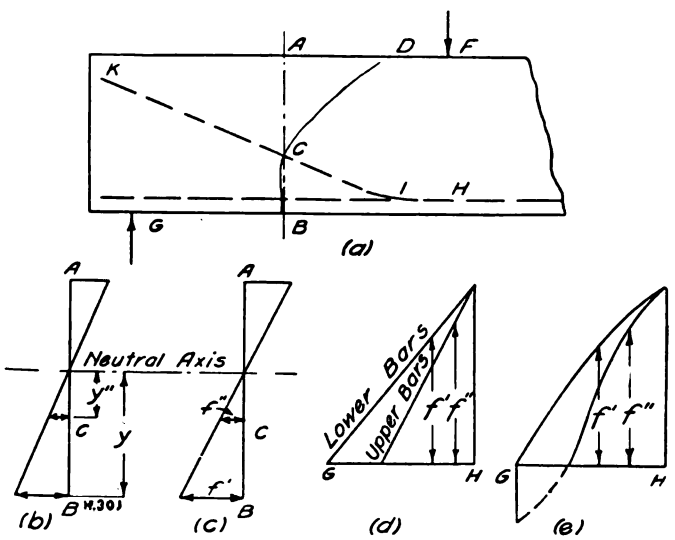

FIG. 4. DIAGONAL TENSION FAILURE IN BEAMS WITH PART OF THE BARS BENT UP.

beam to depth. For comparing the effect of different factors the results of tests have been reduced to a common span length of $8\frac{1}{3}$ ft. (span = 10 *d*) with 1 per cent. reinforcement. *Fig.* 8 gives a number of results reduced in this way.

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Strength of the Beams.—The beams with all reinforcing bars bent up were all of 1 : 2 : 4 concrete and 6 ft. span. In all of them a vertical tension crack appeared between the beam support and the end of the bar, and as the amount of bond brought into action towards the end of the bar is greater than in beams with straight rods there is a greater chance of slipping. When the inclined bars are firmly anchored at their ends, either by bending down or by screwing on nuts and washers, the web strength is greatly increased, and there are indications of arch action. Such a form of construction is a safeguard against failure at low loads from defective concrete or insufficient bond. It makes little difference whether the bars are bent up to near the top of the beam or to a point 5 in. below the top.

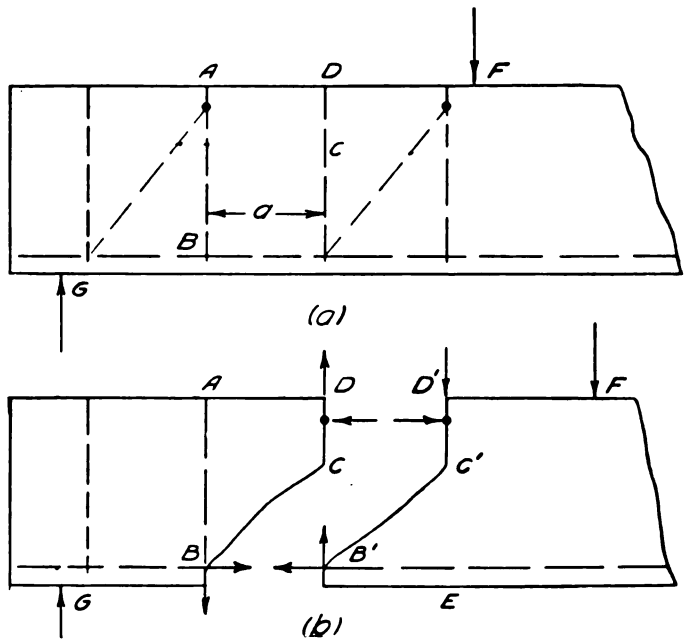

FIG. 5. ACTION OF FORCES IN BEAMS WITH STIRRUPS.

Resistance to Diagonal Tension.—When part only of the bars are bent up, the diagonal bars being well distributed, a high resistance to diagonal tension is developed, being as high as 210-230 lb. per sq. in. (all bars bent only giving 130-150 lb. per sq. in.). Cummings bars give high resistance, averaging 238 lb. per sq. in., the diagonals being well distributed. The welding of the parallel bars at their upper ends is unnecessary, as it would be quite sufficient to bend them into a loop. All these bars failed by tension in the steel.

In beams with stirrups the concrete takes all the diagonal stress until diagonal cracks appear, after which the cracks enlarge considerably, so that failure occurs very slowly. The results of the tests were somewhat indefinite, as failure occurred sometimes by their stretching beyond the elastic limit, or even by their breaking. Some of the beams proved to have been badly made.

Stresses in Stirrups.—The stresses in stirrups were calculated by the formula $P = \frac{V^a}{d'}$ (a is the distance between the stirrups, d' the distance from the centre of

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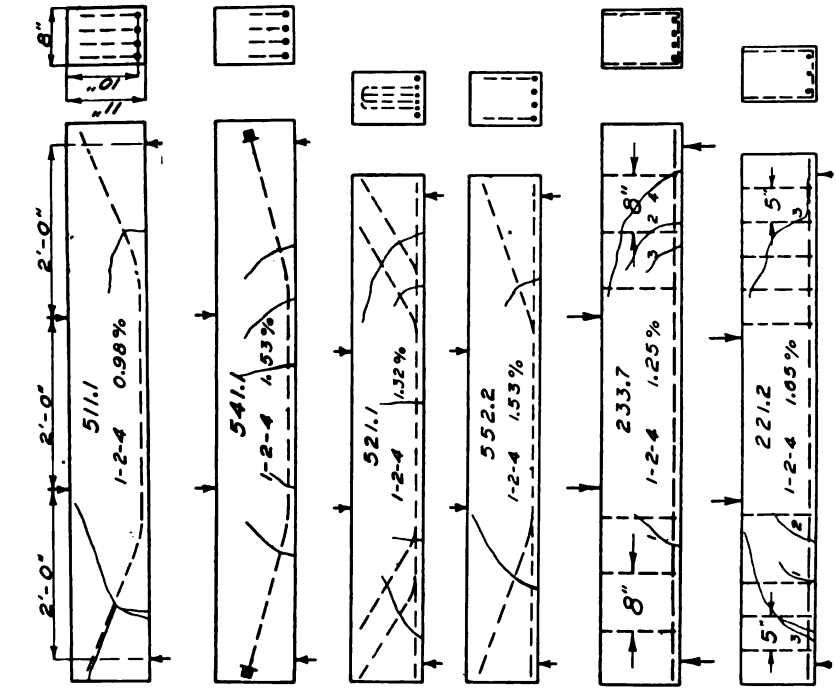

FIG. 7. POSITION OF REINFORCEMENT AND POSITION OF CRACKS.

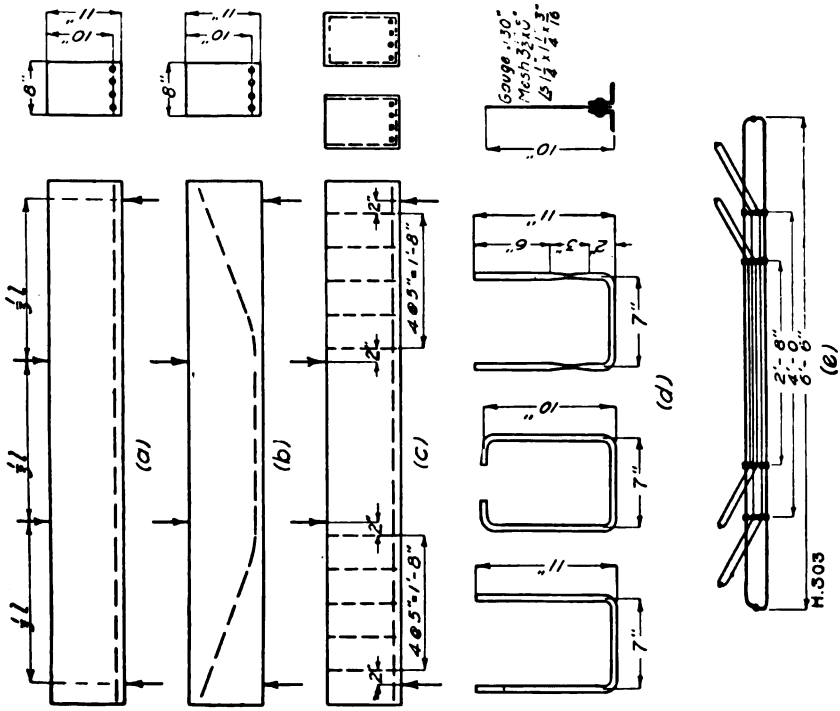

FIG. 6. DETAILS AND ARRANGEMENT OF REINFORCEMENT.

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reinforcement to centre of gravity of the compression area), but the results indicate that the values thus calculated are considerably too high, and two thirds of this value may be safely taken. The spacing of the stirrups should not be more than three-quarters of the depth of the beam. A length of stirrup equal to 0·6 of the depth of the beam may be taken into account for bond. Mild steel is best for stirrups; the use of corrugated bars gives some increased strength.

Conclusion.—The individual results vary very widely, even among beams similar in make-up; it is therefore essential that low web stresses should be assumed in designing. A few typical results are given in *Fig.* 7 and Table I. The first three beams in the table are without web reinforcement, the arrangement of the reinforcement in the remainder is shown in *Fig.* 8.

TABLE I.

Beam	Concrete	Age	Reinforcement		Load at first diagonal crack	Max. load	Stress in longitudinal reinforcement	Nominal vertical shear stress	Nominal bond stress
			Kind	Per cent.					
		Days			lb.	lb.	lb. sq. in.	lb. sq. in.	lb. sq. in.
211·3	1 1½ 3	61	4 × ½" round	0·98	18,000	19,100	34,300	144	194
617·2	1 2 4	57	4 × ⅝" ,,	1·53	18,000	22,250	26,800	173	176
214·3	1 4 8	67	4 × ½" ,,	0·98	14,450	14,450	27,200	113	153
511·1	1 2 4	70	4 × ½" ,,	0·98	13,000	18,000	33,100	138	186
541·1*	,,	61	4 × ⅝" ,,	1·53	16,000	29,600	35,400	229	234
552·2	,,	59	4 × ⅝" ,,	1·53	20,000	29,200	35,000	226	230
521·1*	,,	63	Cummings frame, 2 × ⅝" and 4 × ⅜" round	1·32	22,000	31,100	42,800	238	—
233·7	,,	63	4 × ½" corr. bars, ¼" corr. stirrups	1·25	23,000	27,200	39,500	208	208
221·2	,,	58	3 × ¾" round, ½" round stirrups	1·65	22,000	26,000	29,100	203	230

* Failed by tension.

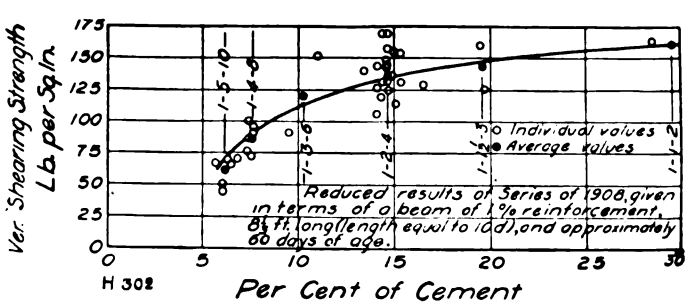

FIG. 8. VALUE OF WEB RESISTANCE.

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GENERAL VIEW IN COURSE OF CONSTRUCTION.

Reinforced Concrete Engine Room for a Dust Destructor at Frankfort.

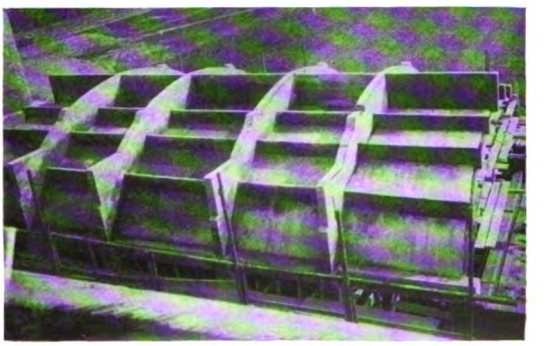
By
ERNST MAUTNER
(Frankfurt).

We are illustrating some interesting drawings and photographs of this engine room as being a characteristic example of the type of work to which reinforced concrete can be economically applied for industrial purposes. In this instance, the work was executed in Germany by Mr. Ernst Mautner (in Firma Aktien-Gesellschaft für Hoch und Tiefbauten, vorm. Gebr. Helfmann in Frankfurt-a-M.), and the particulars are presented with the permission of our German contemporary, "Armierter Beton," in which journal the structure was illustrated in the January issue, 1909.—ED.

LIKE most German cities, Frankfort is now in possession of a large dust destructor, models of which were shown as far back as 1907 at an Exhibition of the Frankfort Architectural and Engineering Association.

The Engine Room.—The engine room, which has recently been completed, is of reinforced concrete, and covers an area of 308 sq. metres (3,315 sq. ft.), having a length of 22 m. (72 ft. 2 in.) to a span of 14 m. (46 ft.). The illustration at the head of this article shows the engine room in course of construction, and it will be observed that its primary feature is the vaulted roof.

It was originally intended that the engine room, which required a height of 15 m. (49 ft. 2½ in.) should be spanned by an elliptical vault. As the side walls, however, were unable to support the thrust of the arch roof, the erection of an actual vault was dispensed with, and girder ribs with The hall was divided into five panel fillings of reinforced concrete construction were substituted.



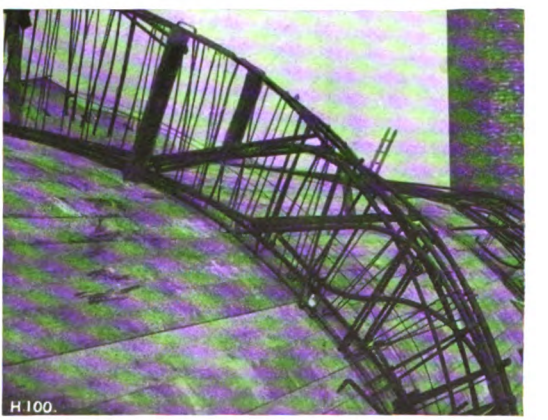


FIG. 2. VIEWS OF THE SKELETON CONSTRUCTION
(Showing spacing of the Rods and back of finished Vault).

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bays by means of these girders. Girders were not provided for the gable walls, and the end bays rest directly on the brick walls. Reinforced purlins span the bays, which in turn carry the reinforced concrete ceiling slabs of 5 cm. (2 in.) thickness. *Fig.* 2 represents views of the skeleton construction, from which the arrangement of the reinforcing beams can be seen.

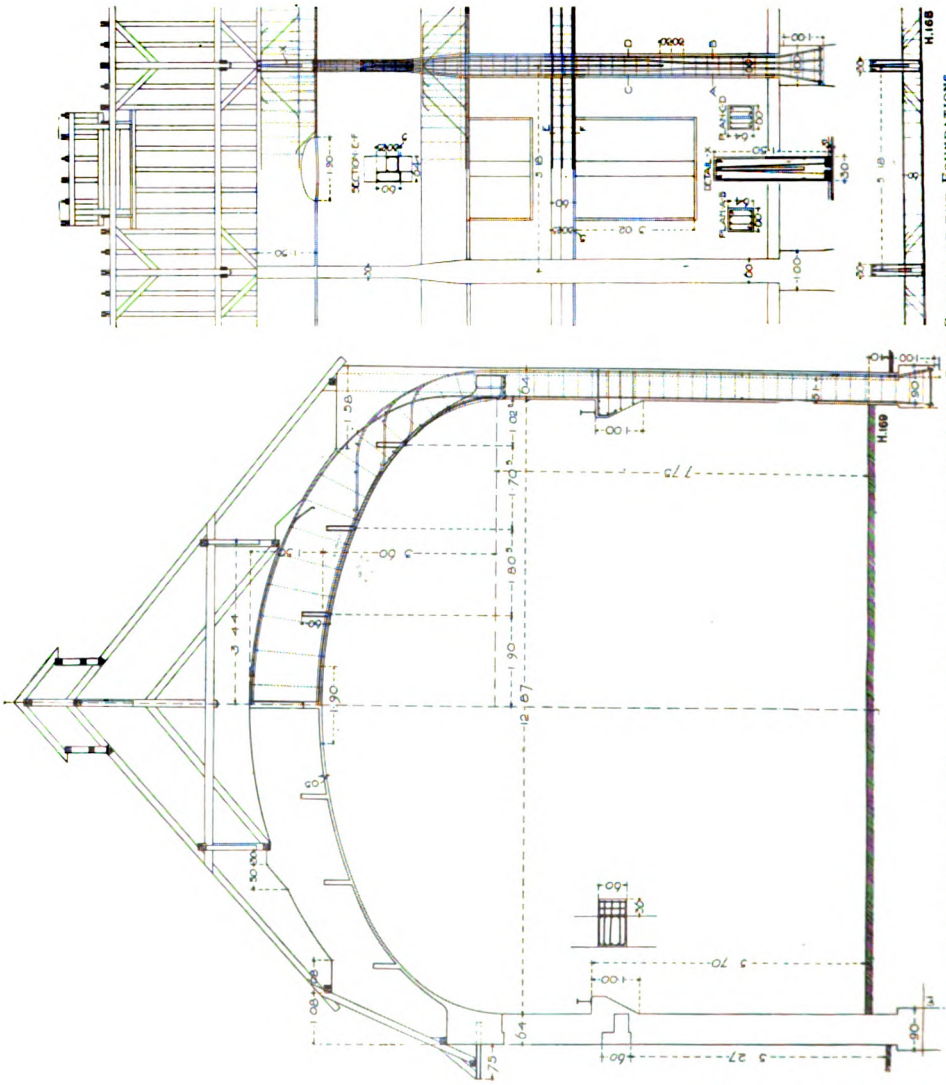

FIG. 3. SHOWING SECTION OF GIRDER, A SECTION OF BAY, AND A VIEW AND CROSS-SECTION OF THE FOUNDATIONS.

Supports.—During construction it was found impossible to rigidly connect the feet of the girder ribs with the supports, and therefore the elliptical rib had to be strengthened. A rigid fixing for the supports could not be obtained on account of the somewhat unstable foundations, and on that account special joints were introduced in the supports in accordance wtih the statical calculation. By this means the uncertainty in the calculation, which is produced only by a partial fixing, was done

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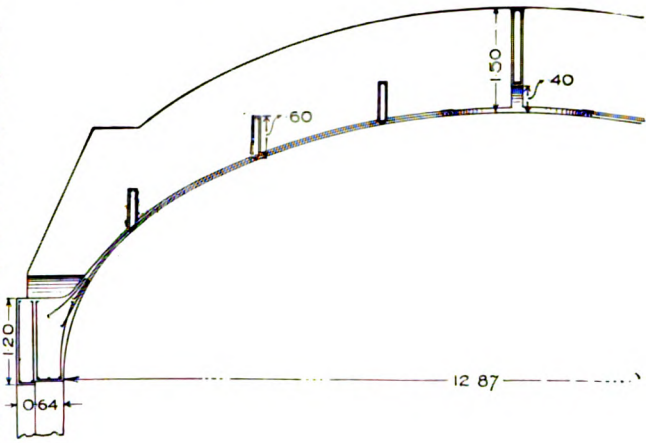
away with. *Fig.* 3 shows a girder, a section through one bay and the arrangement of the foundations.

Foundations.—In the foundations the special joints are at a height of 2·25 m. (7 ft. 4½ in.) above the floor. They consist of carefully executed semi-cylindrical tops on the lower foundation bases, thus ⌒. After suitable hardening, asphalted felt was applied to the tops of these bases, a single layer on curved part and a double layer on the horizontal part. The desired aim of avoiding the transference of the curve of equilibrium to the foundations, and of preventing an actual movement of the joint, was attained, and no deformation was noticeable at this point either at the time of completion of the building or later.



Reinforcement.—The reinforcement of the actual supports consists of four steel rods 26 mm. (1 in.) on the inner side, and four rods of 34 mm. (1⅓ in.) on the outside; at a height of 2·60 m. (8 ft. 6 in.) above the surface line of the ground floor another rod of suitable section was fixed on the two sides. The transverse reinforcement was formed by rods at a distance of 30 cm. (1 ft.), which were so distributed that every three rods were held simultaneously (compare sections a-b and c-d shown in *Fig.* 3).

Brackets were placed in the pillars at a height of 5·70 m. (18 ft. 8½ in.) above the ground floor for the crane, which were firmly fixed to the longitudinal reinforcements of the supports. At the same height the ribs were connected by means of lintols above the lower row of windows of the façade.

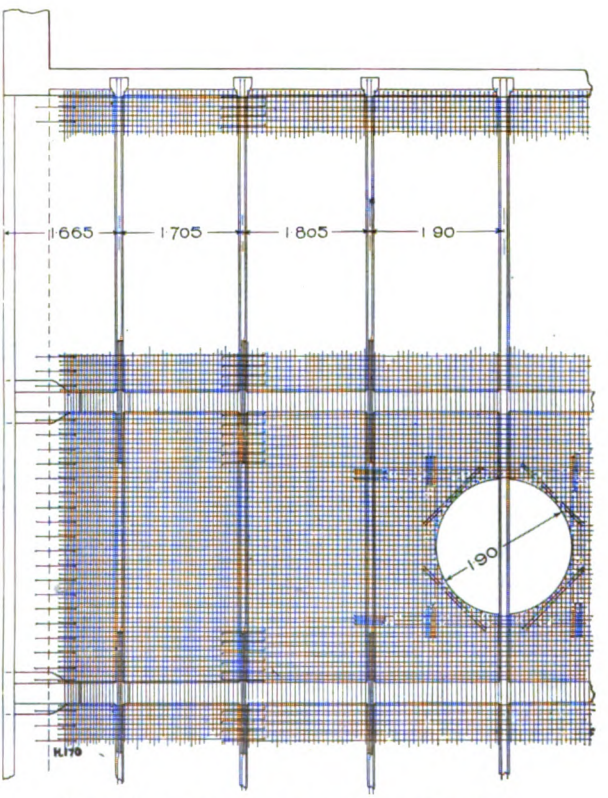


Fig. 4. Reinforced Ceiling and Ventilation Hole.

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At the point of the springing of the vault, heavy lintol beams were fixed on both sides, these supporting the front masonry to the eaves. The lower ends of the pillars measure 60 cm. sq. (2 ft.), tapering to 30 cm. sq. (1 ft.) above.

The sections seen in *Fig.* 3 show the reinforcement of the elliptical part of the ribs, together with the part where the steel reinforcements, in accordance with the position of the curve of equilibrium, cross the rib to receive the thrust of the arch at the same time. The arrangement of the rods at this point is seen in detail x of the longitudinal section.

Seven longitudinal purlins are built in between these ribs, on which the 5 cm. (2 in.) Monier ceiling is fixed.

Fig. 4 represents the Monier ceiling and one of the two ventilation openings.

Execution.—After the completion of the foundations as far as the joints, work was commenced on the entire vault simultaneously with the construction of the centering for the supports and the general scaffolding. The centering of the vault was held in position by props and struts.

After ramming in the supports and the large lintols, the Monier net-work was fixed on the reinforcements of the tie ribs and side ribs, which had already been completed; then the centering for the slabs was set up, filled in and rammed. It was necessary to complete the longitudinal purlins of the two end divisions, which serve as an abutment for the former, before the brick walls were erected. The purlins were, therefore, provisionally supported at the ends by wooden struts.

The façade and rear were erected on their own foundations as non-supporting brick walls.

The reinforced concrete construction of the whole hall as well as the greater part of the reinforced concrete and masonry work of the remaining part of the building were executed by the general contractor named at the head of this article.

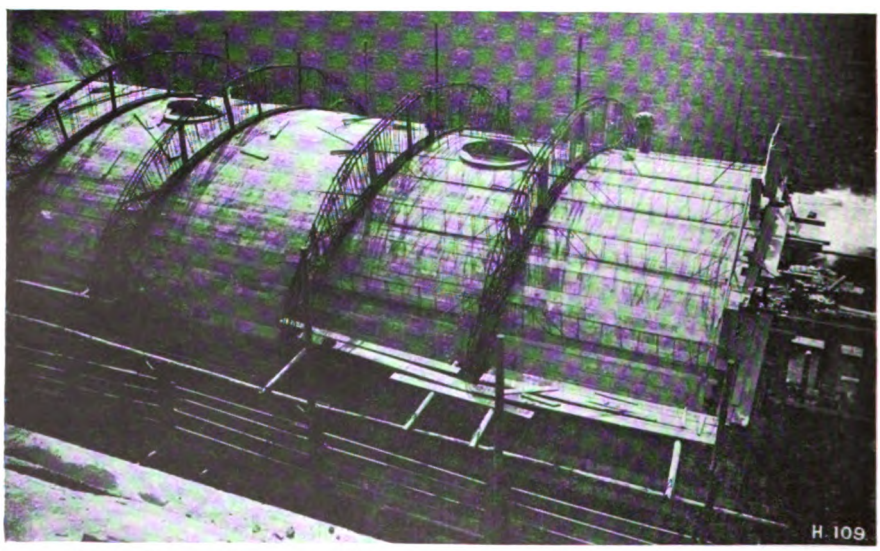

Fig. 5. General View of the Reinforcement of the Roof during Construction.

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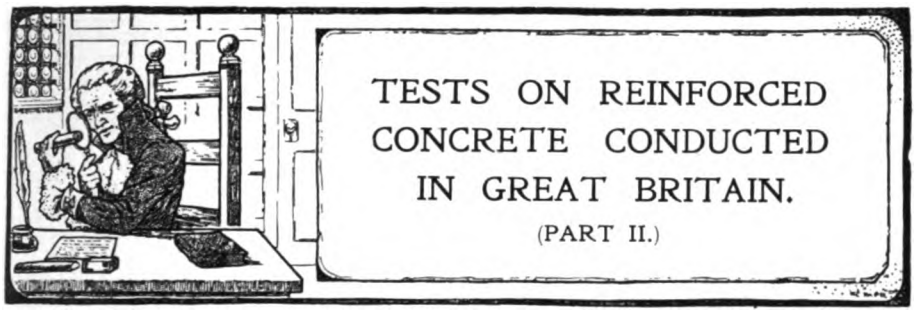

The absence of systematic testing relating to reinforced concrete has placed this country at a disadvantage in the utilisation of this modern material for structural purposes. Excepting only in regard to fire tests, such investigations as have been conducted have been quite spasmodic in character, and practically always of a purely private nature.

Having regard to the fact that the question of a series of tests being conducted in this country, in a systematic manner, is having the attention of the Institution of Civil Engineers, the Concrete Institute, and other scientific societies, we are presenting particulars, as far as we are able, in chronological order, of such tests as have been conducted in this country from time to time, and this may serve as a useful guide to those who have the arrangements of the tests of the future.

The first article of this series appeared in our May issue. In continuation of the previous article the particulars of the following tests are now being presented.—ED.

THE EDWARDS' TESTS.

The next series of tests conducted on reinforced concrete, so far as we can trace, were made by Mr. Frederick George Edwards, who took out patents for constructing reinforced concrete beams and floor slabs in 1891 and 1892. These tests, like Hyatt's, were conducted by Kirkaldy.

The tests were recorded in *Engineering* and *The Builder*, and in Mr. Edwards' patent specifications. It will be noted that there was some special provision made to prevent the concrete shearing or slipping along the bars—namely, by crinkling the ends of the rods, and that some of these rods were turned up or spread out into the concrete at the ends of the beams, as shown in the diagrams.

It will be noted that the Edwards' test beams were of various spans, and their strength was compared with a fir joist, which we have included as of some interest. Edwards records the following facts about the tests. The Portland cement used was "Nine Elms" Brand. He does not state from where the coke breeze was obtained, but we presume it was bought in the ordinary way. The breeze for the 21 days' specimens was screened through a ¼-in. mesh, and that for the 7 days' specimens through a ⅛-in. mesh. The strip of soft concrete inserted in one or both faces of the specimens to receive nails was composed of 1 part Portland cement to 4 parts of fine coke breeze, whereas the ordinary mixture for the remainder of the beams was proportioned 1 : 1. The rods were stated to be of the "Tudhoe Crown" quality of iron; we believe, therefore, that they were of wrought iron.

Edwards goes on to state the following: "The iron rods in each case were firmly held by the concrete, and the ¼-in. rods in the 21 days' specimens must have been on the point of breaking. Sufficient holding surface can always be obtained for the required quantity of iron, for while the sectional area of a rod varies as the square of the diameter, the surface exposed for the adhesion of the concrete varies only as the diameter. For instance, two ¼-in. rods, although one-half the sectional area of one ½-in. rod, have exactly the same amount of surface for the adhesion of concrete. The rectangular specimens with the coarser breeze (which gave the best results), were only seven days old, but were nearly half the strength of the best fir timber. As the concrete at this age has reached only a moderate proportion of its ultimate strength, the strength of fir timber will be easily ascertained, and the quantity of iron required for that purpose can be easily inserted. The large deflection of the composite beam should also be noted, as this shows that they are capable of withstanding suddenly applied loads."

The results of these tests are given in Table II.

Edwards' 1892 patent deals with the inclining of some of the rods at the ends towards the upper surface of the beam for the purpose of resisting what he calls shearing stresses; he evidently means the slipping of the bars, or what is termed adhesion.

In the 1894 patent Edwards describes another test which was conducted by Messrs. Kirkaldy & Son. *Fig.* 7 is a half-elevation, and *Fig.* 8 a central section of this beam, which was 2 in. wide by 6 in. deep by 4 ft. 2½ in., with a clear span of 4 ft. It is described as a model of girders intended to be constructed as long as 40 ft., and Edwards uses the data obtained from its breaking load to calculate the breaking load on girders of a similar kind of 10 ft., 20 ft., and 40 ft. span. The test beam had

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TABLE II.—EDWARDS' TESTS, 1891.

	A	B	C	D	E	F	G	H	J	K	L
Construction tested	Concrete joist, 1½″ flanges, and 1½″ web	Concrete joist	Concrete partition stud, with 1″ flanges	Concrete partition stud, with 1″ flanges	Concrete ground joist, 1″ flanges and 1½″ web	Concrete ground joist, 1″ flanges and 1½″ web	Concrete ground joist	Concrete ground joist	Concrete beam	Fir joist, first quality Gothenburg	Concrete lintel
Size and Dimensions	7″ × 3″	7″ × 3″	4″ × 2″	4″ × 2″	5″ × 3″	5″ × 3″	5″ × 3″	5″ × 3″	5″ × 3″	5″ × 3″	5″ × 3″
Clear span.	10′	10′	10′	10′	6′	6′	6′	6′	6′	6′	3′ 6″
Size and details and area or percentage of reinforcement.	6 ¼″ iron rods in bottom flange, and 2′ in the top flange	3 ½″ iron rods in the underside	3/16″ iron rods in each flange	3/16″ iron rods in each flange	4 ¼″ iron rods in the bottom flange	4 ¼″ iron rods in the bottom flange	3 ⅜″ iron rods in the underside	3 ⅜″ iron rods in the underside	None	None	6 3/16″ iron rods, curved to follow tensile stresses
Date when made.	—	—	—	—	—	—	—	—	—	—	—
Date when tested.	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891	April 30, 1891
Age.	21 days	7 days	21 days	21 days	21 days	21 days	7 days	7 days	7 days	—	7 days
Superincumbent load applied centrally.	2,853 lbs.	2,874 lbs.	416 lbs.	377 lbs.	2,369 lbs.	2,021 lbs.	2,494 lbs.	2,508 lbs.	431 lbs.	5,438 lbs.	4,607 lbs.
Deflection at centre at first crack.	·93″	1·48″	·71″	·78″	·51″	·63″	·92″	·86″	·06″	1·38″	0·42″
Total breaking load	2,867 lbs.	Lever did not rise	Lever did not rise	Lever did not rise	Lever did not rise	Lever did not rise	Lever did not rise	Lever did not rise	431 lbs.	6,107 lbs.	5,104 lbs.
Total deflection at breaking load.	2·02″	5″	5″	5″	5″	5″	5″	5″	·06″	2·12″	·55″
Diagram showing construction.	Fig. 1	Rectangular Fig. 2	Fig. 3	Fig. 3	Fig. 4	Fig. 4	Rectangular Fig. 5	Rectangular Fig. 5	Rectangular	Rectangular	Rectangular Fig. 6
Size gauge of aggregate (screened coke breeze).	¼″ mesh	½″ mesh	½″ mesh	½″ mesh	½″ mesh	½″ mesh	¼″ mesh	—	—	¼″ mesh	—
Remarks.	Bottom cracked and destroyed	Cracked at top	Bottom cracked	Bottom cracked	Bottom cracked	Bottom cracked	Bottom cracked and top crushed	Bottom cracked and top crushed	Broke across	First failure. Top side crushed	Destroyed; cracked also at end bearings
	Strip of soft concrete in top flange, ½″ × 1″	Do. on top, ¾″ × 1⅛″	Do. on each flange, ½″ × 1″	Ditto	Ditto at top, ½″ × 1″	Ditto	Ditto at top, ¾″ × ⅛″	Ditto	—	Final failure. Bottom gave way	—

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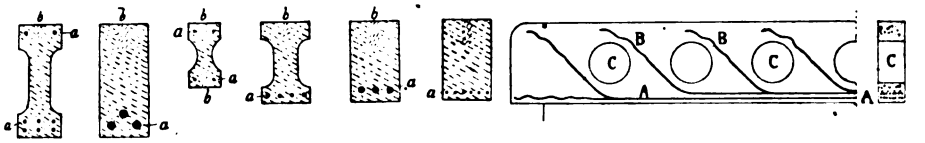
twenty ½-in. dia. iron wires or 10 I.W.G., shown at A embedded in the underside at the centre. The four top rods, shown in the section (*Fig.* 8), were immediately curved upwards at an angle of 45°, and the rest were similarly curved upwards in sets of four at intervals of 6 in., as shown at B in *Fig.* 7,



FIGS. 1 2 3 4 5 6 7 8

EDWARDS' TEST BEAMS, 1891.

leaving four horizontal wires to reach to the ends. The ends of all the wires were corrugated or crinkled, and the concrete was pierced by seven circular openings (C) of 3-in. dia. The beam was composed of 1 part Portland cement to 1 part coke breeze. It was made on April 19th, 1892, and tested August 11th, 1894, thus being 1 year and 8 months old when tested, the load being applied at the bottom of the central opening. It was rightly described as a severe test. A stress of 1,870 lb. produced a deflection of 0·1 in., and the ultimate strength was 5,726 lb., when the deflection was 0·4 in. The failure occurred by the bottom of the joist breaking away.

It may be noted that this patent shows that Edwards clearly defined the cranking up of rods in concrete beams to resist shear stresses, and he described the principle of crankling up the main tension rods for this purpose, so using the metal effectively as they were not required below owing to the gradual decrease in the bending moment as the supports were approached.

THE POTTER TEST.

The Edwards' patents were taken up by Mr. Thomas Potter, well-known as a contractor in concrete for many years past, and the author of the book "Concrete." Mr. Thomas Potter, instead of crinkling the rods, as advised by Edwards, seems to have crinkled the rods throughout their length, and placed them vertically in the concrete. In 1906 he conducted experiments on a floor reinforced in this manner, and the results of the experiments are given below, with all the data with which we have been furnished. The construction is also shown in *Fig.* 9 :—

The floor was supported on four steel joists, these bearing on concrete supports at each corner

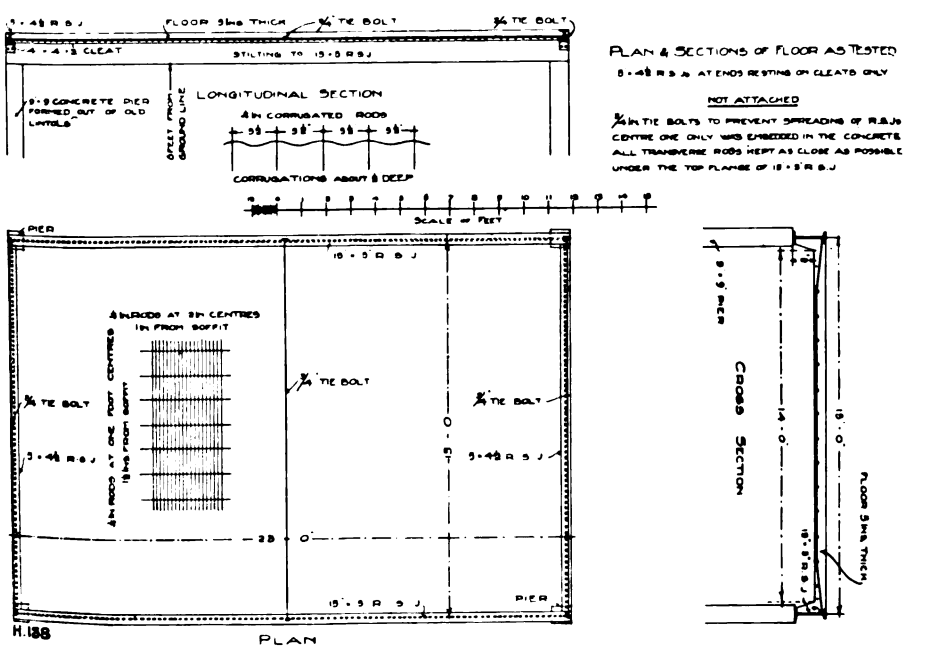


FIG. 9. POTTER'S TEST, 1906.

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about 2 ft. by 2 ft. The floor measured 22 ft. 4½ in. by 14 ft. in the clear of the flanges of joists. The concrete was 5 in. thick, and composed of 1 part of White's Portland cement and 4½ parts by measure of ashes from an electric lighting station, screened through a 1½-in. screen. The reinforcement consisted of ¼ in. round corrugated or crinkled steel rods embedded longitudinally at 12 in. centres, and over same similar rods embedded 2¼ in. centres. The second day after completion the concrete was grouted with 1 of cement to 2 of sharp sand worked in with a broom. The floor was concreted on April 5th, 1906. On July 18th it was loaded with 59 lb. per ft. super, the deflection in centre being less than ⅛ in. The following day the load was increased to 118 lb. per ft.—the deflection being less than ⅛ in. The floor was left in this state till August 9th. Mr. Asbridge, the district surveyor, came on that day and saw it loaded to 254 lb. per ft., the deflection then being 1 in. The piers commencing to settle, no greater load was practicable, one pier having sunk 4⅜ in., and as a result the deflection in centre was 1⅞ in. At this stage slight cracks commenced at the corners in a diagonal direction. When the live load was removed, the floor recovered its position within ¼ in.—*i.e.*, with ¼ in. permanent deflection. Mr. Potter thinks that if the pier had not unfortunately sunk, a much greater load would have been practicable. When the concrete was broken up the reinforced rods had no rust whatever on them. Mr. Potter states that, as a result of the previous experiments, the strength of the floor was about 60 per cent. of its ultimate strength.

TESTS BY STUART'S GRANOLITHIC CO., 1892.

On August 11th and 12th, 1892, Messrs. Stuart's Granolithic Paving Co., Ltd., had a number of slabs and arches reinforced with iron rods tested before a gathering of architects and engineers. With regard to the reinforcements used in these test constructions, unfortunately the exact data do not appear to have been kept, but we are informed that the reinforcement consisted of a meshwork of rods formed by laying ¼-in. rods spaced 6-in. centre to centre directly on ¼-in. rods spaced at 3-in. centres, embedded about ½ in. from the soffit. Probably rods, except where stated, were square in section. In drawing conclusions from these tests, the doubtful nature of the data as regards their reinforcement should be noted, so that any considerable discrepancy cannot be regarded as establishing any new features in the behaviour of reinforced concrete under loading. The data as to the loading and deflection we have on the authority of Mr. W. A. Thomas, M.Inst.C.E., M.I.M.E., who reported upon the tests. In one—namely, the No. 7 arch—Mr. Thomas states that the lacing was of ¼-in. square iron rods, while in the case of the No. 8 arch slab the reinforcement consisted of ¼-in. round rods. In the No. 9 arch slab he states the reinforcement consisted of patent meshing with $\frac{1}{16}$ in. by ⅛-in. lacings. He also states that the weight of a 2-in. "granolithic" floor was about 24 lb. per sq. ft., inclusive of lacing. In a 6 ft. by 6 ft. slab he calculated the quantity of iron, ¼-in. by 3-in. mesh, to be 60 lb., so that the iron rods must have been of square section, and spaced at 3-in. centres each way.

In connection with these experiments some tests were conducted by Messrs. Kirkaldy & Son as to the crushing resistance of the concrete employed. The specimens of these tests possessed the great merit of having been obtained from the actual test specimens in the larger experiments, they therefore provide very exact data as to the strength of the concrete. It is to be noted that the strength is given in cube form, and that these cubes were sawn or cut from the concrete, and might have been slightly injured in so obtaining them, while as regards the shape of the test piece, Professor Bauschinger showed many years ago that the strength of a cube in compression did not represent the actual crushing resistance of a brittle material. The 2-in. cubes were crushed between pieces of pine boards ⅜-in. thick, which would increase the resistance unduly. The results gave a mean resistance of about 3,400 lb. per sq. in.

The experiments that have been conducted in order to ascertain the actual crushing strength in specimens of concrete upon a proper basis—namely, a test specimen having a length one and a half times the width of the side, are very few, and insufficient data are available to make any definite pronouncement on the subject. From Professor Bauschinger's results on stone, it would appear that the results obtained with cubes were 10 per cent. higher than would have been obtained with an improved form of test piece, but a few rough experiments suggest that with concrete much greater variance may exist. It should be remembered, however, that the few tests that have been made upon concrete sawn from full size work have shown much greater resistance than cubes made experimentally at the same time and with the same materials; indeed, it seems that concrete in the mass obtains a greater strength than in small pieces. However, here again, full data are, so far as we are aware, not available, and further investigation is required to offer any satisfactory opinion on the subject.

We might mention that Messrs. Stuart's Granolithic Co., Ltd., had been constructing floors reinforced with iron rods for some years previously to the tests above recorded, and the work is in existence to-day, and no defects have been reported.

These 1892 tests are recorded in Table III. :—

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TABLE III.—STUART'S GRANOLITHIC 1892 TESTS.

GENERAL PARTICULARS.—The concrete was composed of finely crushed granite and Portland cement, except where otherwise stated. Age 3 months. The load was applied uniformly with bags of cement or granite which had been previously weighed.

No.	Nature of Construction.	Dimensions.	Clear Span.	Details of Reinforcement.	Loading.		Remarks.
					Total Load.	Per sq. ft.	
		Length, Width, Depth.					
1	Flat slab, supported on all edges by timber frame.	6′ × 6′ × 2″	5′ 6″	Meshwork of rods.	8 tons.	5·35 cwt.	No failure under this load.
2	Arched slab, supported between deals, tied together by two ⅜″ rods to form abutments.	5′ 6″ × 7′ × 2″ rise 5½″	5′ 6″	Ditto.	At 8 tons, ⅛″ deflection; at 12½ tons, ⅜″ deflection.	6·32 cwt.	Ditto.
3	Ditto, but made of sand and cement.	5′ 6″ × 7′ × 2″ rise 5½″	5′ 6″	Ditto.	Cracked down middle at 5 tons.	6·07 cwt.	—
4	Flat slab, supported at two sides only, made of sand and cement.	6′ × 6′ × 2″	5′ 6″	Ditto.	Deflected 6″ under 4 tons.	2·43 cwt.	—
5	Flat slab, supported on all edges by timber frame.	6′ × 6′ × 2″	5′ 6″	Ditto.	2 cwt. dropped on it from a height of 7 ft. producing impact of 42½ cwt.	—	First blow dented; second blow increased dent, and broke some of rods and slightly cracked slab; third blow at another place broke some rods, but did not crack slab. No deflection.
6	Arch with haunches filled in, supported between deals, tied together by three ⅜″ rods.	5′ 6½″ × 7′ × 2″ rise 5½″	5′ 6″	Ditto.	At 15½ tons, ⅛″ deflection.	8·85 cwt.	No failure at this load.
7	Ditto, but made of sand and cement.	5′ 6½″ × 7′ × 2″ rise 5½″	5′ 6″	¼″ sq. iron mesh work.	Sustained 9 tons.	5·15 cwt.	Ditto.
8	Arched slab, made of sand and cement.	5′ 8″ × 3′ 4″ rise 5½″	5′ 8″	¼″ round iron meshwork.	Broke at 4 tons 4 cwt.	4·47 cwt.	—
9	Ditto.	5′ 8″ × 3′ 4″ rise 5½″	5′ 8″	Patent meshing of 1/16″ × ⅛″ lacings.	Broke at 2 tons 10 cwt.	2·66 cwt	—

TABLE V.—W. B. WILKINSON & CO., LTD., TESTS FEBRUARY 3rd, 1896.

Concrete composed of 3 parts crushed bricks to 1 part Portland cement

No.	Age when Tested	Nature of Construction	Dimensions	Clear Span	Diagram showing Construction	Reinforcement	Loading Central Deflection in inches at centre with a load as follows in tons.										Breaking Load in tons.
							1½	2	2½	3	3½	4	5	6	7	8	
			Width Dpth.	ft.													
3	2 years	Beam	4″ × 6″	5	I	One joist 3″ × 1¼″ × 4 lbs. per foot	·032	·063	·09	·125	·156	—	—	—	—	—	4·0
4	Ditto	Ditto	Ditto	5	Ditto	Ditto	—	·032	·062	·09	·125	·187	—	—	—	—	4·5
5	Ditto	Ditto	Ditto	5	Ditto	Ditto	·031	·063	·09	·156	·19	—	—	—	—	—	3·85
6	Ditto	Ditto	Ditto	5	Ditto	Ditto	·031	·063	·09	·125	·16	—	—	—	—	—	4·0
7	Ditto	Ditto	Ditto	5	Ditto	Ditto	·031	·063	·09	·12	·15	—	—	—	—	—	4·0
8	Ditto	Ditto	Ditto	5	V	One bar, 1½″ × 1½″ × ¼″	·031	·125	·18	—	—	—	—	—	—	—	2·9
9	Ditto	Ditto	6″ × 8″	5	I	One joist, 4″ × 1⅞″ × 8 lbs. per foot	—	·031	—	·062	—	·093	·125	·157	·187	·25	8·5

The beams in tests Nos. 3 and 4 were oiled. In test No. 5 the beam split by shearing and partly by compression on top edge. In all the beams the concrete cracked on the bottom edge. In test No. 8 the concrete cracked on the bottom edge and also sheared. In tests Nos. 3–8 the steel beams were below the neutral axis. In test No. 9 the beam was in the centre of the concrete. The breaking load of the steel joist by itself in tests Nos. 3–7 was 2 tons in the centre, and of the steel joist in No. 9 3·6 tons.

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TABLE IV—STUART'S GRANOLITHIC, 1903—1904, TESTS.

General Particulars.—The concrete was composed as given below. The loading took place by means of cast-iron collector shoes, each weighing about 42 lbs. each, placed 9 in each layer. When the layers rose to a great height, the loading could not be carried quite to end; thus the increased weight in centre about offset the slight arching that may have taken place in the load. The slab was supported on timber sleepers, at two ends or edges only. The reinforcements were about ¼ in. above the soffit, or ⅝ in. from soffit to centre of rods. Cement used was Portland, supplied by Associated Portland Cement Manufacturers (1900) Ltd.

No.	Date.	Age when Tested.	Nature of Construction.	Kind and Proportion of Concrete.	Dimensions.	Clear Span.	Details of Reinforcement.	Loading (weight of 2″ slab adds about 226 lbs.).	Ultimate Load.	Remarks.
					Length Width D'pth	ft.				
1	Dec. 4, 1903.	24 days.	Flat Slab.	3 : 1 crushed granite.	7′ 6″ × 1′ 7″ × 2½″	7	6 ¾″ round rods 7′ 5″ long. Total section = ·6 sq. in. Transverse rods, 1′ 6″ long—*i.e.*, 3″ mesh. Intersections tied with 22 B.W.G.	Deflection appeared to go by 1-16ths of inch after second layer of load was applied. Distributed load.	6,268 lbs.	Deflection at centre, 1 7/16″.
2	Ditto.	24 days.	Ditto.	Ditto.	7′ 6″ × 1′ 7″ × 2″	7	Ditto.	Ditto.	4,059 lbs.	Deflection at centre, 1½″.
3	Jan. 1, 1904.	50 days.	Ditto.	Ditto.	7′ 6″ × 1′ 7″ × 2″	7	Ditto.	See (*a*) below.	5,000 lbs.	Deflection at centre, 1 11/16″. Fracture first occurred on compression side, approximately across centre of slab.
4	Ditto.	50 days.	Ditto.	Ditto.	7′ 6″ × 1′ 7″ × 2½″	7	Ditto.	See (*b*) below.	6,426 lbs.	Deflection at centre, 1½″. Fracture first occurred on tension side of slab, probably indicating drawing of iron rods.
5	Jan. 16, 1904.	23 days.	Ditto.	Ditto.	7′ 6″ × 1′ 7″ × 2″	7	Expanded metal. Section ·6 sq. in.	—	1·28 tons	Deflection, 1⅛″.
6	Ditto.	23 days.	Ditto.	Ditto.	Ditto.	7	Barbed wire, 6 wires, 7′ 6″ long; 14 wires, 1′ 6″ long. Section ·6 sq. in.	—	·375 tons	—
7	Jan. 18, 1904.	11 months.	Ditto.	Ditto.	11′ 6″ × 1′ 0″ × 1′ 3″	10	3 ⅜″ round rods at top, 6 ⅝″ square rods below. Section of steel, 1·98 sq. in.	Central loading.	18·4 tons	·47″ deflection at 40,000 lbs.
8	March 9, 1904.	35 days.	Ditto.	4 : 1 crushed granite.	7′ 6″ × 1′ 7″ × 2½″	7	9 ¼″ round rods 7′ 6″ long, 8 ¼″ round rods 5′ 6″ long, each spaced alternately. Section of steel = ·83 sq. in.	Distributed loading. Slab weighed 350 lbs. extra. See (*c*) below.	7,182 lbs.	Bent to 60°. Initial stress applied, 5,000 lbs.
9	Ditto.	Ditto.	Ditto.	4 : 1 sifted Thames ballast.	Ditto.	7	Ditto.	See (*d*) below.	8,562 lbs.	—
10	April 22, 1904.	Not stated.	Ditto.	3 : 1 Thames ballast.	7′ 6″ × 1′ 7″ × 2″	7	As Nos. 1–4.	Distributed loading.	2·75 tons	Deflection at centre, 1¾″.
11	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	7	Ditto.	Ditto.	2·75 tons	Ditto.

(*a*) Load	1134	1512	1890	2268	2646	3024	3402	3780	4158	4536	4914	(*c*) Load	756	1512	2268	2648	3024	3402	3780	4158	4536	4914	5292	5670	6048	6426	6804
Defn.	3/16″	1/2″	9/16″	25/32″	27/32″	1″	1 1/32″	1 3/16″	1 5/32″	1 1/8″	1 11/32″	Defn.	1/16″	1/4″	3/8″	13/32″	15/16″	5/8″	42/32″	1 5/16″	7/8″	1″	1 3/32″	3/16″	1 11/32″	1½″	1 19/32″
(*b*) Load	1134	1890	2268	2646	3024	3780	4530	4914	5292	5670	6048	(*d*) Load	756	1512	2268	3024	3780	4536	5292	6048	6426	6304	7182	7642	8102		
Defn.	3/16″	9/8″	7/16″	1/2″	19/32″	3/4″	7/8″	31/32″	1 1/32″	1 5/32″	1 3/16″	Defn.	1/16″	3/32″	3/32″	13/32″	19/32″	19/32″	23/32″	31/32″	25/32″	31/32″	1 3/32″	1 3/32″	1 5/32″		

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Some tests on slabs constructed of concrete and reinforced with round rods were conducted, in order to satisfy Mr. Basil Mott, partner to Sir Benjamin Baker, and engineer to the Central London Railway, by Stuart's Granolithic Stone Co. at Shepherd's Bush in 1903 and 1904, and particulars of these tests are given in Table IV.

MISCELLANEOUS TESTS.

Since 1873 Monier had been gradually extending the application of his system, and Cottançin, Coignet, Hennebique, and others, from about 1890 to 1893, had brought out their systems in France and Belgium, and from about 1898 onwards a gradually increased volume of work was being done by the Hennebique firm in this country, and Wayss and Freytag, who are chiefly responsible for pushing the Monier system in Austria and Germany, and scientifically applying it, got their system taken up by the Armoured Concrete Construction Co., Ltd., in England, about 1902. We, therefore, find that though nothing much had been done in the way of tests, there was a gradual growth of knowledge respecting the work and investigations that were being done abroad, and with work beginning to be carried out in England, it was natural that more enterprise in this direction should be shown.

The Hennebique agents in this country conducted various tests on completed floors and other structures from 1898 onwards; but full details of the disposition and sizes of the reinforcements, etc., are not available, so that we do not record the loads applied and the facts observed, which, without such data, are of no scientific value.

We understand that various tests from time to time were conducted by W. B. Wilkinson upon floors in various buildings that he had constructed upon his system, but we are unable to obtain data, as the records of the early work of the firm by him are not available, having, we believe, been destroyed in the fire that occurred in their offices. It is unfortunate, because it would have been very interesting to have traced the early development of reinforced concrete.

Some beams of concrete, reinforced with steel in various sections, were made by Mr. Phillip Hobbs, managing director of Messrs. W. B. Wilkinson & Co., Ltd., Newcastle-on-Tyne, and tested by Professor Weighton on February 3rd, 1896, and described in a paper read by Mr. Hobbs for the Northern Architectural Association. The beams were made of concrete, 3 parts crushed brick to 1 of cement, and tested by a load applied at the centre on a span of 5 ft. The steel in each case was 1-20th the sectional area of the concrete. Two of the 6-in. by 4-in. beams had the joists embedded therein coated with oil to prevent adhesion, but beams of the same size and position of joist, but with a web bulged to prevent slipping, did not sustain any greater load. In all these narrow beams the shearing of the concrete occurred at the upper edges of the joists. The 6-in. by 4-in. beams were all two years old, and had been exposed to the extremes of temperature to see if any damage would be done to the concrete with the expansion and contraction of the joists. "So far as one could tell," it is recorded, "no movement of any sort had taken place." The coefficient of strength of these small beams, Mr. Hobbs records, is 50, as compared with 39 for the larger beams owing to the more advantageous position of the steel joist. (See Table V.)

TESTS WITH EXPANDED METAL, 1896.

The next series of tests which we have to record were carried out in 1896, when some tests were conducted by the late Sir John Fowler and the late Mr. Benjamin Baker upon nineteen slabs and six arches reinforced with expanded metal. The quality of the materials used was Portland cement, weighing 85 lb. per cu. ft., leaving 1¾ per cent. residue on a 2,500 mesh sieve, and affording a strength of 560 lb. per sq. in. net at seven days, and 278 lb. per sq. in. sand briquettes, 3 to 1 for 28 days. The sand employed was clean Leighton Buzzard, weighing 96½ lb. per cu. ft., and of such coarseness as to remain on a sieve of 10 meshes to the inch. The gravel was clean Thames ballast, weighing 95 lb. per cu. ft. The expanded metal was a very mild steel, having an ultimate resistance of 22 tons per sq. in., with 21 per cent. elongation on ⅛-in. Two sets of expanded metal were used, one 3-in. mesh with strands $\frac{7}{32}$-in. by $\frac{3}{32}$-in., the other being stronger, of 3-in. mesh with strands $\frac{7}{32}$-in. by $\frac{5}{32}$-in. The concrete was composed of 1 cement, 1 unscreened sand, and 2 screened and washed Thames ballast ¾-in. mesh, mixed by hand and rammed in place, the mixture being what is known as "dry," about half the volume of water being added, and the slabs were 3-in. thick. The slabs and arches were kept under cover, protected from frost and other atmospheric influences. It is stated in their report that experiments, conducted in April, 1895, that is a year before the report in question, with expanded metal in combination with concrete slabs of 2-ft. 6-in. span, showed that a 3-in. mesh with ⅛-in. by $\frac{7}{32}$-in. strands would give equivalent results to those obtained by the use of $\frac{7}{32}$-in. by $\frac{3}{32}$-in. metal in slabs of 3-ft. 6-in. span, as in the present case. The loading was evenly distributed by means of rails averaging 6 cwt. each. Table VI. gives full details of the tests.

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TABLE VI.—EXPANDED METAL COMPANY. TESTS BY FOWLER & BAKER.

	A	B	C	D	E	F	G	H	I	J	K	L	M
Construction tested	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Plain concrete slabs	Slab made with expanded metal	Slab made with expanded metal
Size and Dimensions	4′ × 2′ × 3″	7′ × 2′ × 3″	4′ × 2′ × 3″	7′ × 2′ × 3″	4′ × 2′ × 3″	7′ × 2′ × 3″	7′ × 2′ × 3″	4′ × 2′ × 3″	4′ × 2′ × 3″	4′ × 2′ × 3″	4′ × 2′ × 3″	7′ × 2′ × 3″	4′ × 2′ × 3″
Clear Span	3′ 6″	6′ 6″	3′ 6″	6′ 6″	3′ 6″	6′ 6″	6′ 6″	3′ 6″	3′ 6″	3′ × 6″	3′ 6″	6′ 6″	3′ 6″
Size and details and area or percentage of reinforcement	None	None	None	None	None	None	None	None	None	None	None	6′ 8″ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	4′ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″
Date when made	Jan. 20, 1896	Jan. 20, 1896	Jan. 20, 1896	Jan. 20, 1896	Jan. 20, 1896	Jan. 20, 1896	Jan. 20, 1896	Jan. 20, 1896	Jan. 30, 1896	Jan. 30, 1896	Jan. 30, 1896	Jan. 1, 1896	Jan. 1, 1896
Date when tested	Mar. 23, 1896	Mar. 23, 1896	Mar. 23, 1896	Mar. 23, 1896	Mar. 23, 1896	Mar. 23, 1896	Mar. 23, 1896	Mar. 23, 1896	April 17, 1896	April 17, 1896	April 17, 1896	Mar. 4, 1896	Mar. 4, 1896
Age	63 days	63 days	63 days	63 days	63 days	63 days	63 days	63 days	77 days	77 days	77 days	63 days	63 days
Ultimate deflection at centre	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	No appreciable deflection	$1\frac{1}{8}$″	$\frac{15}{32}$″
Total breaking load, cwts.	30	18	36	18	18	6	6	18	18	12	18	60	84
Breaking load, cwts. per sq. ft.	4·28	1·39	5·14	1·39	2·57	0·46	0·46	2·57	2·57	1·71	2·57	4·61	12·00
Remarks	Concrete made 3 cement, 1 sand, $1\frac{1}{8}$ water	Concrete made 3 cement, 1 sand, $1\frac{1}{8}$ water	Concrete made 3 cement, 1 sand, $1\frac{1}{8}$ water	Concrete made 3 cement, 1 sand, $1\frac{1}{8}$ water	Concrete made 1 cement, 2 Thames ballast, 1 sand, $\frac{1}{2}$ water	Concrete made 1 cement, 2 Thames ballast, 1 sand, $\frac{1}{2}$ water	Concrete made 1 cement, 2 Thames ballast, 1 sand, $\frac{1}{2}$ water	Concrete made 1 cement, 2 Thames ballast, 1 sand, $\frac{1}{2}$ water	Concrete made 3 neat cement, 1 water	Concrete made 1 cement, 2 sand, $\frac{1}{2}$ water	Concrete made 1 cement, 1 sand, $\frac{4}{5}$ water	Broken in centre. The strands of metal were broken through	Broken under one timber. The strands of expanded metal were broken through

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TABLE VI.—continued.

	N	O	P	Q	R	S	T	U	V	W	X	Y
Construction tested	Slab made with expanded metal	Slab made with expanded metal	Slab made with expanded metal	Slab made with expanded metal	Slab made with expanded metal	Slab made with expanded metal	Concrete arch	Concrete arch	Concrete arch	Concrete arch	Concrete arch	Concrete arch
Size and Dimensions	7′ × 2′ × 3″	4′ × 2′ × 3″	7′ × 2′ × 3″	4′ × 2′ × 3″	4′ × 2′ × 3″	7′ × 2′ × 3″	3′ wide, 3″ thick at crown, 5″ rise	3′ wide, 3″ thick at crown, 5″ rise	3′ wide, 3″ thick at crown, 5″ rise	2′ wide, 2″ thick at crown, 3″ rise	2′ wide, 2″ thick at crown, 3″ rise	2′ wide, 2″ thick at crown, 3″ rise
Clear Span	6′ 6″	3′ 6″	6′ 6″	3′ 6″	3′ 6″	6′ 6″	6′ 6″	6′ 6″	6′ 6″	3′ 6″	3′ 6″	3′ 6″
Size and details and area or percentage of reinforcement	6′ 8″ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	4′ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	6′ 8″ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	4′ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	4′ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	6′ 8″ × 2′ × 3″ mesh, strand $\frac{7}{32}$″ × $\frac{3}{32}$″	—	—	—	—	—	—
Date when made	Jan. 17, 1896	Jan. 17, 1896	Jan. 30, 1896	Jan. 30, 1896	Jan. 30, 1896	Jan. 30, 1896	Jan. 21, 1896	Jan. 21, 1896	Jan. 21, 1896	Jan. 21, 1896	Jan. 21, 1896	Jan. 21, 1896
Date when tested	Mar. 20, 1896	Mar. 20, 1896	April 17, 1896	April 17, 1896	April 17, 1896	April 17, 1896	Mar. 23, 1896	Mar. 24, 1896	Mar. 24, 1896	Mar. 24, 1896	Mar. 25, 1896	Mar. 25, 1896
Age	63 days	63 days	77 days	77 days	77 days	77 days	62 days	63 days	63 days	63 days	64 days	64 days
Ultimate deflection at centre	$1\frac{1}{8}$″	$\frac{9}{32}$″	$1\frac{3}{16}$″	$\frac{17}{32}$″	$\frac{13}{32}$″	$1\frac{3}{16}$″	$2\frac{3}{8}$″	—	3·13″	20·57″	24·00″	20·57″
Total breaking load, cwts.	66	120	60	138	150	66	84	—	60	144	168	144
Breaking load, cwts., per sq. ft.	5·08	17·14	4·61	19·73	21·43	5·07	4·31	—	3·13	20·57	24·00	20·57
Remarks	Broken under one timber. The strands of expanded metal were not broken through	Broken under one timber. The strands of expanded metal were not broken through, but concrete sheared	Just carried the weight of tenth rail one second	Carried the twenty-third rail about half minute	Carried the twenty-fifth rail about half minute	Carried the eleventh rail about half minute	At half alternate load—42 cwts.—cracked at centre, which increased to $\frac{5}{16}$″ before collapse. Concrete 1 : 2 : 1 : $\frac{1}{2}$ water	Arch damaged; not tested. Concrete 1 : 2 : 1 : $\frac{1}{2}$ water	Cracked when $\frac{1}{4}$ breaking load was on. Concrete 3 : 1 sand : $1\frac{1}{2}$ water	$\frac{5}{8}$ of load was on, and then work left until next day; broke suddenly. Concrete 1 : 2 : 1 : $\frac{1}{2}$ water	Broke gradually Concrete 1 : 2 : 1 : $\frac{1}{2}$ water	Concrete 3 : 1 sand : $1\frac{1}{2}$ water

NOTE.—The average weight of rails is taken at 6 cwts. each.

(To be continued.)

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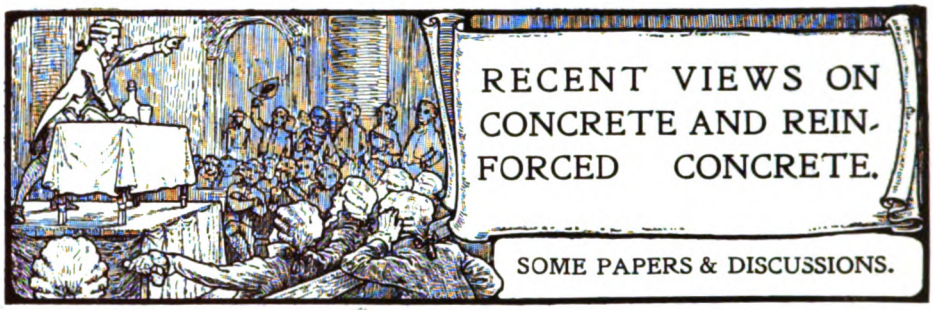

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.

The method we are adopting, of dividing the subjects into sections, is, we believe, a new departure.

We trust that this chapter of our journal may become a recognised reference medium as to the latest views of those who can speak with authority.—ED.

SOCIETY OF ARCHITECTS.

THE DANGERS OF BREEZE CONCRETE.

Paper by MR. D. B. BUTLER, A.M.Inst.C.E., F.C.S.

Before the members of the Society of Architects, Mr. D. B. Butler, A.M.Inst.C.E., F.C.S., delivered a lecture, illustrated by lantern views of diagrams, on "The Dangers of Breeze Concrete." Mr. Ellis Marsland (Hon. Secretary) presided.

Mr. Butler said that during the past few years he had met with instances of failure of concrete composed of Portland cement and breeze, failures, as a general rule, caused by the expansion of the mass, resulting in more or less serious consequences to the structure of which it formed part. These failures had generally occurred where the concrete had been used to form flat roofs or fireproof concrete floors, on the well-known embedded rolled joist system of construction. In some instances the expansion had been but slight, though noticeable; in others it had been sufficient to push out the brickwork walls, causing serious bulging, and thus endangering the safety of the whole structure. Careful investigation of some of the foregoing causes of failure justified the opinion that the mischief lay with the cement, but in many instances the most careful and searching investigation, both chemical and physical, disclosed nothing sufficiently definite in character to enable the investigator to lay his finger with positive certainty on the cause of the trouble. In nearly all the samples of so-called breeze concrete a very considerable quantity of material other than pure coke was noticeable in the aggregate, such as clinkers, stones, shale, ashes, etc., together with, in some instances, a noticeable amount of coal. The question arose, however, whether, apart from being undesirable for the reasons aforesaid, either coke breeze or coal was in any way dangerous as being likely to cause expansion of the concrete.

Experiments.—The lecturer then described some experiments with coke breeze, and illustrated his remarks with tables and diagrams. The first experiment was of a somewhat rough-and-ready nature, and was made with coal. An ordinary bituminous house coal was crushed and sifted to about the fineness of standard sand—*i.e.*, passed through a $\frac{1}{20}$ in. sieve and retained on a $\frac{1}{30}$ in. With this coal a 3 to 1 mortar was made, and two small 2-oz. glass bottles filled with the mixture. One bottle was filled quite full, and the other was filled to within $\frac{1}{4}$ in. of the top and sealed down with a paste of neat cement, the object of the sealing being to ascertain whether the imprisonment of any hydrocarbons set free from the coal would have any bursting effect. For comparative purposes a similar bottle was also filled with a paste of neat cement and 3 to 1 mortar of standard sand. Sixteen cements of various qualities and different origin were tried, some being sound when tested for expansion by the Faija test and the Le Chatelier boiling test, and some otherwise. The samples were those which passed through the lecturer's hands for testing in the usual course, and were not specially chosen, except for the purpose of obtaining as varied a selection as possible.

Results.—The whole of the bottles eventually cracked, with the exception of one filled with standard sand-cement mortar. But while those filled with the coal mortar generally cracked within two or three days, and with very few exceptions continued to expand until the bottles burst away into several pieces, those filled with the neat cement and the sand mortar frequently did not develop any cracks whatever till several months, and it was the exception rather than the rule for them to

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continue expanding sufficiently to burst the bottle. Both the neat cement and sand-cement mortar bottles remained perfectly sound after eleven months, and then only developed minute cracks, whereas the coal mortar bottle was cracked in 12 days, and burst right off in 42 days. This suggested that the cause of the cracking after such protracted periods might be due to unequal expansion of the glass and the mortars at varying temperatures. Though the bottle test was only a rough one, it served to show that coal developed dangerously expanded properties when mixed with cement, but since there was no clearly marked difference between those bottles sealed down with neat cement and those unsealed, it did not favour the theory that the expansion was in any way due to the evolution of the gas within the mortar.

Testing Samples.—The next step was to test samples of so-called "breeze" of various origin to ascertain if the coal sometimes present (probably partially burned) was unsafe, and also if there were other constituents present which might prove detrimental. Several samples of good breeze were procured; also some which he was assured by the breeze merchant would never be sanctioned by a good clerk of the works. The constituents of the latter, however, did not differ materially from the ingredients to be found in breeze concrete from the many important constructive works.

With all the samples tested the general method was to separate them into their several fractions or constituents, so as to be able to identify, if possible, the cause of the expansion, if any. Each sample was therefore carefully separated out as follows:—

(1) The fine material passing through a $\frac{1}{16}$-in. sieve.

(2) The fine material passing through a $\frac{1}{4}$-in. sieve, but retained on a $\frac{1}{16}$-in. sieve.

(3) The coarse material retained on a $\frac{1}{4}$-in. sieve. This was picked over by hand, and separated out into its various constituents, such as clinkers, coal, coke, etc.

An "average" sample was also prepared, being (1), (2), and (3) mixed together in their proper proportions.

The variety of the materials in some of the samples of so-called "breeze" was considerable, and, in addition to coal, coke, and clinkers, rubbish of all sorts was present, such as bits of steel saw, nails, brass, and iron turnings, and other metal fragments, broken pottery, etc. The percentage of each fraction was carefully recorded, and, as a convenient size for making into mortar for testing purposes, each fraction was broken up to pass a $\frac{1}{16}$-in. sieve. Two cements of previously ascertained stability of volume were used for the experiments—A, produced from the well-known lias formations near Rugby; B, produced from the chalk marl deposits and clay in the midland counties.

Bottle Test.—The bottle test previously described as having been carried out with the coal mortars was somewhat crude, and also qualitative rather than quantitative; moreover, it might be conceivably influenced by the difference between the coefficient of expansion of the glass and of the mortars at different temperatures. In order, therefore, to render them more accurate and of a quantitative nature, the subsequent experiments with coke breeze mortars were made with prisms or rectangular bars 100 mm. long and 22 mm. by 22 mm. cross-section, the expansion and contraction of which were accurately measured in the Bauschinger Micrometer Calliper apparatus.

With cement and standard sand eight bars or prisms were made with each kind of cement, four being made with neat cement and four with 3 to 1 standard sand-cement mortar. Two of each series were kept entirely in air, and two placed in water after 24 hours, and kept therein during the three months with which this record deals. With the same cements, prisms were prepared from each of the fractions of the ten different samples of breeze experimented with, and treated as above—*i.e.*, half kept in air, half put in water, and measured periodically.

Noticeable Features.—A noticeable feature of the experiments was that many of the specimens which showed very marked expansion when placed under water as soon as set, expanded very much less when left entirely in air. It therefore seemed a point worth determining as to whether exposure to damp or moisture would in any way effect these air-set specimens at the end of three months' tests—*i.e.*, after they had become thoroughly seasoned.

One of the duplicate air bars from each series was therefore placed under water, the time elapsing between the date of moulding and placing under water ranging from 91 to 292 days. Immersion had practically no effect upon those specimens which had previously shown no expansion when kept under water, but it caused almost immediate expansion of a very serious nature with those fractions of breeze which had previously developed expansion when placed under water in the first instance. This clearly showed that the expansive agent was more or less dormant in the dry air-set block, and only required to become damped to constitute a serious element of danger.

Conclusions.—Taken as a whole, the experiments seemed to point to the fact that, as regards subsequent expansion, there was not much danger to be apprehended from good clean coke or clinkers, or even anthracite coal, but that some kinds of ashes and furnace refuse were highly dangerous, while any considerable quantity of bituminous coal was absolutely fatal. Another noticeable feature was that most of the coke-breeze mortars had a tendency more or less seriously to attack the iron moulds in which the Bauschinger bars were made, causing them to rust during the short space of 24 hours

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between the moulding of the specimens and their removal from the moulds. The lecturer was unaware if such results had been found to any appreciable extent in actual practice, but samples of breeze concrete sent to him for examination recently showed distinct marks of considerable rusting having taken place where the concrete had been in contact with the rolled joists. If such proved to be the case, it might in the end prove a very serious matter as affecting the life and strength of the steel work.

Altogether the experiments described represented some two years' work, and included the preparation of about 300 test pieces, involving some 5,000 measurements, to say nothing of the sifting, sorting, and preparation of the breeze samples. These were far from reaching finality; indeed, they only touched the fringe of a wide field of research, in which there was a vast amount of work to be done. He trusted, however, that the foregoing researches might prove of value, and tend to prevent the recurrence of such failures in the future.

DISCUSSION.

Rust.—*Professor Henry Adams, M.Inst.C.E*, in thanking the author for his paper, pointed out the significance of his statement as to the tendency of coke breeze and mortar to cause rusting of the bars. The Concrete Institute were making a special investigation in connection with the subject, and the author's results were of great value.

Failures.—*Mr. H. K. G. Bamber, F.C.S.*, said he rather hoped they would have had some well-defined chemical results to account for the failures referred to, but he was inclined to believe that such failures were caused by chemical action set up by the presence of sulphur compounds in the coke when mixed with the Portland cement.

Dampness.—*Mr. Max Clarke, F.R.I.B.A.*, gave instances of failures with coke breeze floors, but in many of the cases brought to his notice dampness usually played an important part in the failure. From nvestigations that he made regarding failures with coke breeze he found on analysis that coke contained a considerable amount of sulphur, which would rather corroborate Mr. Bamber's idea.

Expansion.—*Mr. H. E. Hawker, F.R.I.B.A.*, said he had overcome the difficulty of expansion during the last twelve months by reinforcing his floors with wire or expanded metal.

Destructor Clinker.—*Mr. Wm. Marsh, M.Inst.C.E.*, suggested that destructor clinker might be used instead of coke breeze for floors where lightness was required; but

Mr. Ling considered that this material was not suitable, as they were apt to get only partially burned matter, which would cause blowing.

Sulphur Compounds.—*Mr. Anderson* said he also considered that they should be careful in the use of coke breeze or slag in the construction of fire-resisting floors, as these materials were liable to contain sulphur compounds.

Proper Coke Breeze.—The Chairman was of opinion that the whole crux of the matter lay in the architect seeing that he really got coke breeze when he specified it, for at present much of the so-called coke breeze was rubbish got from anywhere. He considered that the tests carried out by the British Fire Prevention Committee proved beyond a doubt that coke-breeze floors were fire-resisting. It was true that the underpart might become incandescent, but the fire did not come through. He also advocated the carrying out of tests with larger blocks of material, so that it would be possible to get some idea of what would happen in actual practice.

The Reader of the Paper Replies.—*The lecturer*, in a brief reply, said he was inclined to agree with the chairman that success or failure largely depended upon getting the article which was specified. He defined coke breeze as fine coke, but it was a fact that what was often supplied was not coke breeze in the true sense of the term. His experience went to show that when the concrete had expanded it remained permanently expanded, and did not subsequently contract. A water engineer had told him that it had been found where coke breeze concrete was used for covering in iron pipes considerable rusting always occurred.

INSTITUTION OF MUNICIPAL ENGINEERS.

ESSENTIAL FORMULÆ IN STRUCTURAL ENGINEERING.

Paper by Mr. HORACE CUBITT, A.R.I.B.A.

We give the following extract of a paper read before the members of the Institution of Municipal Engineers by Mr. Horace Cubitt. Mr. John T. Pegge, President of the Institution, presided.

Text-books.—Formulæ have been stated to constitute a mathematician's shorthand. From this it would seem evident that, where the facts which it is desired to represent are in no way complex or involved, the use of formulæ, or, in other words, the use of shorthand, is not necessary. Unfortunately, however, the large majority of engineering, and even architectural, text-books attempt to carry a cargo of formulæ which, instead of acting as useful ballast, is of such ponderosity as almost to sink the ship

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of the reader's interest and attention. My quarrel with the ordinary text-books is twofold: in the first place, because they quote formulæ for cases which can quite easily be worked out without such "aids"; and, secondly, because formulæ which are really necessary are often so disguised by inversions and transpositions of all kinds, and by the lack of standardisation in the symbols, that the average student, who in excess of zeal consults two or three text-books, usually gets his ideas of the subject hopelessly confused. In the present paper it will be my endeavour to demonstrate that, when a proper analysis of the question is made, the real essential formulæ for structural engineering purposes will be found able to be counted on the fingers of one hand.

Different Members.—The several members met with in structural work are able to be grouped under four heads:—

(1) Where the forces act directly away from the member, producing tension.

(2) Where the forces act directly to the member, producing in the first instance chiefly compression.

(3) Where the forces act in a transverse direction to the axis of the member and induce a bending tendency, tension compression and shear being consequently produced.

(4) Where members are subjected at the same time not only to direct tension or compression, but also to compression tension and shear due to bending.

Members in Tension.—In this case once the total stresses have been calculated—in framed structures usually with the aid of graphics—the determination of the required sectional area of the member to resist such stresses is most simple. No one thinks of using a formula. The ordinary rules of arithmetic, applied with common-sense, are in every way sufficient. There being no complex problem, the use of shorthand—or formulæ—is not necessary.

Members in Compression.—Dealing with the most elementary form of construction coming under this heading—ordinary walls—calculations to determine thickness are rarely necessary. The thickness of walls is almost always fixed by schedule. But it is often necessary to calculate the size of piers carrying considerable weight. In this case no formula is used, the weight on the piers and the consequent load per unit of area are worked out by ordinary arithmetic.

Reinforced Concrete Pillars.—Coming to the question of reinforced concrete pillars we find that in the report of the Reinforced Concrete Committee convened by the Royal Institute of British Architects, a formula is given which is applicable to columns whose lengths do not exceed eighteen times their least dimension, and in which the reinforcing bars are satisfactorily tied together in order to resist any bending tendency. Upon a little investigation, however, the process of calculation is seen to be so simple that to deal with it by means of symbolic representation appears merely an unnecessary burdening of one's memory with symbols. To obtain the safe bearing capacity of such a pillar, it is simply necessary to find the sectional area of the whole pillar, add to this fourteen times the sectional area of the steel, and treat the combined area thus obtained as that of a plain concrete pillar in direct compression. To me it is more reasonable to think of this in plain English than to have recourse to symbols.

Steel Resistance.—Those, however, not familiar with the subject may ask why the area of the stee is multiplied by such an apparently arbitrary figure as 14. The reason is that the respective moduli of elasticity of steel and concrete in compression are in the ratio to one another of 15 to 1. With the materials acting together the steel therefore provides a resistance per unit of area fifteen times that of concrete. If the steel is stressed so as to provide more than this resistance the concrete will suffer. It is therefore necessary to add to the area of the concrete fifteen times the area of the steel. But, taking the area of the whole reinforced pillar, this obviously includes both the area of the concrete and—putting it thus for the sake of clearness—one times the area of the steel; consequently, it is necessary to add to the total area of the pillar fifteen *minus* one—viz., fourteen times the area of the steel.

Determining Strength.—When wood struts and iron and steel stanchions of a length customary in ordinary practice are considered the circumstances are different. In addition to the direct pressure there is the tendency to fail by bending, and to an average person it is practically impossible without formulæ to carry in the memory all factors which have effect in determining the strength of such members. Formulæ here appear to be essential, and of these it is generally considered that the most reliable is the adaptation by Professor Rankine of Gordon's formula.

Essential Formulæ (1)

(as applicable to steel columns and stanchions).

$$p = \frac{f}{1 + a\frac{l^2}{r^2}}$$

where p = unit breaking stress
f = unit elastic limit of material in compression (about 18 tons per square inch)
l = length
r = least radius of gyration
} The same units of force, length and area being respectively taken throughout.

a = a factor usually taken as:—

$\frac{1}{18000}$ for free ends,
$\frac{1}{36000}$ for fixed ends.

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When this formula is used for calculating the strength of cast-iron columns or stanchions and wood struts, the constant a is usually taken respectively as eight and twelve times the value given above, and the value of f in the case of cast iron will be about 35, and in the case of deal struts about 2·2 tons per sq. in.

Factor of Safety.—Many authorities, however, consider that this formula should be applied, not with a fixed factor of safety, but that it should be used in connection with some other formula giving a greater factor of safety in accordance with the increased liability of failure due to an increase in the ratio of length to least radius of gyration. Probably the most simple and appropriate factor of safety formula for steel stanchions is :—

$$\text{Factor of safety} = 4 + \frac{1}{100} \times \frac{l}{r},$$

l and r being in the same units,

which was given by Mr. E. Fiander Etchells in a paper read before the Civil and Mechanical Engineers' Society last year.

Members Subject to Bending.—It is with regard to members of this nature that modern text-books are responsible chiefly for confusion. In the early days of scientific research and the formation of engineering formulæ it was customary in every case to deal separately with the moment of resistance and the bending moment.

Essential Formulæ (2).

$$M_r = M_b$$

when M_r = the moment of resistance
when M_b = the bending moment
} The same units of force, length, and area being respectively taken throughout.

To make these as near as possibly equal and thus provide efficiency with economy was the object of the engineer, and by the use of such simple and straightforward methods the solution of engineering problems was on a very clear and logical basis. Of late years it has become customary to depart from this simplicity and to quote formulæ applicable only to central distributed and other similar symmetric forms of loading, and with the symbols transposed in a manner to facilitate easy, and unfortunately blind, methods of working.

Loads.—If, and this is the point I wish particularly to emphasise, nothing but central and evenly distributed loads were met with in practice there would be no great objection to this procedure. But loads unfortunately are so inconsiderate as not to adapt themselves to such formulæ, and very often are irregularly placed. I am afraid there are not a few of the younger generation who, while quite competent by means of the "stock" formulæ to work out problems where the loads are central or distributed, are unable to deal with a collection of "point" loads irregularly spaced on a girder. They have not devoted the necessary attention to the quite simple method of finding the bending moment of a supported beam—a method, of course, applicable to all kinds of loading.

Formulæ for Beams.—The formulæ for beams given in the report of the R.I.B.A. Reinforced Concrete Committee need perhaps some little investigation before it is discovered that to a great extent they are old friends in new dresses. It is desirable first to look back and realise the exact principles upon which all beam formulæ are based.

In the modern type of steel joist composed of a single material offering equal resistance to compressive and tensile stresses the area of the compression flange has to be exactly equal to that of the tension flange, and the neutral axis is situated at the half-depth of the section. In the old, practically obsolete, type of cast-iron girder—a girder composed of material offering much greater resistance to compressive than to tensile stresses—the circumstances are different, and the area of the tension flange must be about six times greater than the minimum area of the compression flange in order that the material may be stressed according to its respective capabilities in tension and compression, and the neutral axis in this case does not coincide with the half depth, but with the centre of gravity of the section.

Reinforced Concrete.—Coming to reinforced concrete, we have here a combination of materials, of which not only is the safe stress of the steel, which takes up the tension, about twenty-seven times that of the concrete which takes up the compression, but also a further difference of characteristics has to be considered, as the modulus of elasticity of the steel is about fifteen times greater than that of the concrete. The steel, that is to say, is this much stiffer than the concrete. Thus, prior to the ultimate provision of the materials in the ratio demanded by their respective safe resistances—a process to some extent analogous to that adopted in the case of a cast-iron beam—it is necessary to find the neutral axis, for the position of this will greatly affect the moments of the resisting stresses in the steel and concrete.

Neutral Axis.—The finding of the position of the neutral axis is probably the most difficult of the several operations necessary in the calculation of a reinforced concrete beam, and in ordinary calculaons the position arrived at is only hypothetical, for the neutral axis in such beams varies in position

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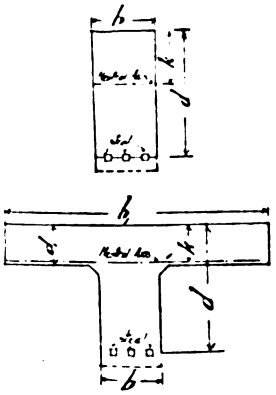
according to the extent of the loading of the beam and the consequent variations in the moduli of elasticity of both materials. The old beam theory that sections remain plane sections both before and after bending is generally accepted for the purpose of practical calculations for reinforced concrete beams. Many authorities, indeed, question its exact theoretical applicability to such beams, but almost all admit that the results of calculations on such basis are sufficiently near for practical purposes. The position of the neutral axis varies in accordance with the ratio of the area of steel to the area of the concrete, and also in accordance with the ratio of the moduli of elasticity of the two materials. In practice, however, the ratio between the two moduli being taken as constant the position of the neutral axis in any particular beam of fixed sectional area varies only in accordance with the ratio of the area of the steel to the area of the concrete, or with, as it is more often termed, the percentage of reinforcement, any increase in the area of the steel causing the neutral axis to become closer to the steel.

Calculations.—The calculations for finding the position of the neutral axis are so involved that a formula becomes quite an essential aid. But recourse to calculations for finding the neutral axis will rarely be necessary in the case of beams not connected to slabs, for the values of k for varying percentages of reinforcement are given in the report of the R.I.B.A. Reinforced Concrete Committee and in most reinforced concrete text-books, k being the proportion of the depth (measured from the top) at which the neutral axis is situated.



The values of k given in the R.I.B.A. report for a few ordinary percentages are :—

0·7 per cent.	or	·007	ratio of steel to concrete			·365
1·0	,,	,, ·010	,,	,,	,,	·417
1·5	,,	,, ·015	,,	,,	,,	·483
2·0	,,	,, ·020	,,	,,	,,	·530

When, however, a T-beam, in which the floor slab assists the ordinary rectangular beam, is dealt with, the depth of the neutral axis does not vary in any fixed proportion with the amount of reinforcement. The use of a formula in this case is therefore necessary, and as the formulæ applicable to T-beams are derived in a similar manner to that applying to ordinary rectangular beams, all three are given.

Essential Formulæ (3).

rectangular beam $k=\sqrt{(p^2m^2+2pm)}-pm$

T-Beams · $k=\sqrt{\frac{2A_tm}{b_1d}+\frac{A_t^2m^2}{b_1^2d^2}}-\frac{A_tm}{b_1d}$

T-beams where the neutral axis comes *below* the slab.

$$kd=\frac{b_1d_1^2+2A_tmd}{2b_1d_1+2A_tm}$$

the distance, previously $\frac{1}{3}kd$, equalling $\frac{d_1}{3}\times\frac{3kd-2d_1}{2kd-d_1}$

when (the above being the R.I.B.A. Committee's symbols)—

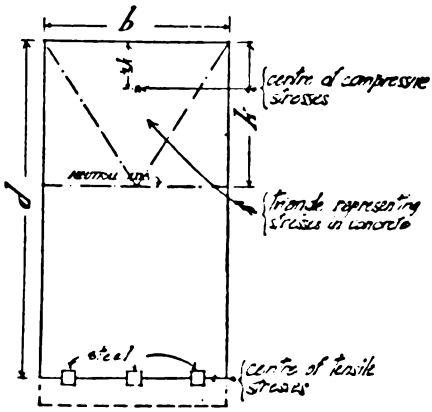
k = the proportion of the depth of the beam (measured from the top) at which the neutral axis is situated
b = breadth of beam
b_1 = breadth of the portion considered as the table of the T
d = total depth of beam
d_1 = depth of slab
A_t = area of steel in tension

} The same units of length and area being respectively used throughout

$p=\frac{A_t}{bd}$ = ratio of section of metal to section of concrete (often termed the percentage of reinforcement)

$m=\frac{E_s}{E_c}$ = ratio of moduli of elasticity of steel (in tension) and concrete (in compression) —usually 15

Tensile and Compressive Stresses. — The position of the neutral axis having been ascertained, it will be well to note the position of the centres of the tensile and compressive stresses in the beam. As regards the steel, the centre of the tensile stresses will obviously coincide with the centre of gravity of the metal. As regards the concrete, the stresses, as in the case of all rectangular beams, vary from zero at the neutral axis to maximum at the outermost layer, and may be represented in the form of a triangle, and the centre of such compressive stresses is situated at the centre of gravity of this imaginary triangle, which is to say, one-third the height of the triangle or one-third k.



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Calculating Strength of Beams.—Coming now to the method of calculating the strength of beams of reinforced concrete, in ordinary cases it will be found that the beams are not merely supported beams, but that they are to some extent either fixed at the ends or continuous over supports, and in practice where loads are distributed it is a general custom to allow for a bending moment of $\frac{WL}{12}$ at the centre and $\frac{WL}{24}$ at the supports. In the case of slabs the bending moment will be $\frac{WL}{12}$ if the slab is reinforced in only one direction and not exceeding $\frac{WL}{16}$ if reinforced in both directions.

The R.I.B.A. Reinforced Concrete Committee give the following formulæ for working out rectangular beams :—

$M = A_t t(d - \frac{1}{3}kd)$ which is the moment of resistance of the steel, and $M = \frac{1}{2}A_c c(d - \frac{1}{3}kd)$, which is the moment of resistance of the concrete.

When A_t = area of steel in tension, A_c = area of concrete in compression, M = bending moment, t = unit tensile stress in the steel, c = unit compressive stress in the concrete, the same units of force, length and area being taken throughout.

Special Formulæ.—But the use of special formulæ here is not essential, although when the subject is thoroughly understood it greatly conduces to ease and quickness of working. Until a thorough understanding is reached it is well to work on more general lines. It is the old case of the moment of resistance having to be equal to the bending moment. And this moment of resistance in the case of the steel is simply the area of the steel multiplied by the distance between the centres of the tensile and compressive stresses (which result gives in effect the section modulus of the beam as regards the steel), and multiplied again by the safe unit stress of the steel. In the case of the concrete the moment of resistance is the area of so much of the concrete as is on the other side of the neutral axis, multiplied by the distance between the centres of the tensile and compressive stresses (which result gives a figure equal to *twice* the section modulus of the beam as regards the concrete), and multiplied again by *one-half* the safe unit stress of the concrete. The reason why one-half the safe unit stress has to be taken in the case of the concrete is that, as previously stated, the stresses in the concrete vary from zero at the neutral axis to the maximum at the outermost layer, whereas those in the steel are practically uniform, and in considering the resistance of the concrete the *mean* stress on the whole of the concrete above the neutral axis has been considered. But if this *mean* stress on the concrete is allowed to reach the safe unit stress, the *extreme* stress at the outermost layer, which is exactly double the mean stress, will consequently be double the safe stress of the material, which, of course, must on no account be allowed.

Shear.—In addition to the compression and tension in beams of any material, there is also the shear to be considered. This can easily be obtained without formulæ, the shear at the supports being equal to the reactions, and the shear at any other point being equal to the amount of the nearest reaction *minus* any load or loads between such point and this reaction. Reinforced concrete beams have been found to fail by what is termed diagonal tension due to shear. The amount of the diagonal tension at any point may be ascertained by finding the resultant of the vertical and the horizontal shear. These shearing stresses, of course, being equal to one another, the resultant is at an angle of 45° with the direction of either of them, and amounts to the stress multiplied by $\sqrt{2}$

Diagonal Tension.—In practice, to obtain the amount of the diagonal tension to be taken up by the steel, it is necessary to consider only so much of the shearing stress as is in excess of the safe resistance of the concrete to vertical shear.

Beams.—In dealing with this question of beams, semi-beams or cantilevers are intended to be included, and it should be remembered that beams are not only horizontal, but very often vertical. There are particularly several kinds of vertical cantilevers met with in ordinary construction. Among these are walls retaining either earth or water, although sometimes such walls are held both at the top and bottom, and thus become beams. High chimney shafts and high enclosure walls subject to wind pressure are other examples of vertical cantilevers.

Bending Moment.—The methods of obtaining the overturning or bending moment, in the case of structures subject either to wind or water pressure, are in no way in dispute. In either case it is the external forces acting at the centre of application multiplied by the distance of such centre of application from the base of the wall. In the case of wind pressure this centre will be at the centre of gravity of the area acted upon by the wind. In the case of water where the pressure varies from zero at the top to maximum at the bottom, and may be graphically illustrated in the form of the triangle, the centre of pressure is at one-third the height of such triangle.

Rankine's Formula.—When, however, earth is dealt with there are numerous formulæ, none of which appear to meet with absolute acceptance, but Rankine's formula is undoubtedly the most well recognised.

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Essential Formulæ (4)

For a bank with a flat top $P = \frac{wh^2}{2} \times \frac{1-\sin\phi}{1+\sin\phi}$

For a bank with a sloping top $P = \frac{wh^2}{2} \times \cos\theta \frac{\cos\theta - \sqrt{\cos^2\theta - \cos^2\phi}}{\cos\theta + \sqrt{\cos^2\theta - \cos^2\phi}}$

when P = the total pressure of earth acting parallel to the surface at a point situated at one-third the height of the wall
w = weight
h = height
ϕ = angle of repose of earth.
θ = angle of slope of top of bank.

The same units of force, length and area applying respectively throughout

It is clear that without some symbolic representation Rankine's method of obtaining the pressure of retained earth would be most difficult both to remember and to apply. The amount of the earth pressure having been obtained the wall can be worked out as a vertical cantilever. Where the wall has a flat top it is also possible to obtain a satisfactory solution of the problem by means of graphics.

Beam Stanchions.—Cases not infrequently occur in practice where a member acts as a tension or compression member, and also as a beam or cantilever subjected to cross-strain. A steel tie beam of a roof, carrying a ceiling suspended at intervals throughout the "span" of the tie beam, is an instance of tension combined with cross-strain being produced. Stanchions eccentrically loaded, and stanchions forming part of a retaining wall, and also bearing a load, and principal rafters carrying purlins at points intermediate between the struts, are instances frequent in occurrence in which allowance has to be made both for compression and cross-strain. The logical method of obtaining the maximum stress on such members is to add to the tensile or compressive stress, due either to direct pull or load, the additional tensile or compressive stress due to the cross-strain. The total tensile or total compressive stress, as the case may be, is thus obtained.

Direct Tension.—In the case of members subjected in the first instance to direct tension, the total tension may, of course, be allowed to reach the safe tensile stress of the material. Dealing, however, with compression members subject also to cross strain, the greatest stress which may be allowed is a much more variable quantity. The case is one for the exercise of some little judgment. Where the stresses due to the direct load are very much greater than those due to the member acting as a beam, it will not be well to exceed the safe stress calculated on the stanchion basis. But where almost the whole of the stresses are due to beam action, a safe stress approximating 7 tons may be allowed.

Conclusion.—Probably it may be said that while proposing to treat of "essential formulæ" I have often strayed some little outside the narrow course to which I might appear committed by the choice of such a title. But a paper rigidly confined to the postulation of a half-dozen formulæ would be but a barren enterprise, although in the hands of a capable enthusiast in this direction it might offer an excellent opportunity for a display of mathematical gymnastics, to the great edification of the author and the awe of the average audience. I have rather attempted to deal with the subject from a practical standpoint, giving formulæ where such are necessary, but not otherwise, in order that my paper may not merely constitute a tilt against the serried ranks of redundant formulæ, but may also contain some information of general value.

DISCUSSION.

Unstable Formulæ.—*Mr. Frank Latham* (Penzance), who opened the discussion, said the references to reinforced concrete were up to date as far as one could see; but the engineer would be wise to keep his eye open with regard to the formulæ for considering reinforced concrete, for improvements were being introduced yearly. He would like to ask whether the author had, in dealing with reinforced concrete, accounted the question of deterioration by rust and such like that might take place in steel.

Bending.—*Mr. J. H. Markham, A.R.I.B.A.* (London), said that the first thing that struck him was the quotation from the report on reinforced concrete of the R.I.B.A. of a formula which was applicable to columns whose lengths did not exceed eighteen times their least dimension, and in which the reinforcing bars were satisfactorily tied together in order to resist any bending tendency. That presumably meant the tendency of the *rods* to bend, and not that of the whole member. It was not altogether an ideal method of treating reinforced concrete compression members, because they were not given any basis for data on which to calculate the stress in the binding members. He fancied that what took place and what seemed to conform to common-sense ideas, was that when the concrete was pressed, it had a tendency to spread laterally, and that there was considerable hoop tension, so that the binding rods did a considerable amount of work. The tendency to spread was resisted by the binding members and by increasing these they increased the strength of the concrete.

Tendency to Spread.—There were systems of reinforcement, such as M. Considère's, in which the spiral system of reinforcement adopted resisted the tendency to spread, and so increased the com-

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pressive resistance of the concrete ; but probably reinforcement in this way would not come under the description given in the paper.

Difference of Characteristics.—His difficulty, however, came in with the author's statement as to reinforced concrete to the effect that they had a combination of materials of which not only was the safe stress of the steel which took up the tension about twenty-seven times that of the concrete which took up the compression, but also a further difference of characteristics had to be considered as the modulus of elasticity of the steel was about fifteen times that of the concrete. He could not understand the stress of the steel being twenty-seven times that of the concrete. He had understood that a definite value had to be assigned to the ratio between the moduli of elasticity of steel and concrete. That was taken in the R.I.B.A. report as being fifteen. When that was accepted it was all they wanted in order to proceed to calculate the position of the neutral axis for any particular percentage of reinforcement.

Stresses.—*Mr. E. F. Etchells, A.M.I.M.E.* (London), stated that the ratio raised by the last speaker, that between the safe stress of steel and the safe stress of concrete (which the author had given as twenty-seven) might be anything in the world in concrete structures as they were to-day. The statement simply meant that if they found out what a concrete block would safely resist, and what a steel cube would resist, the ratio between the two was about that amount, say, 16,000 lb. stress on the steel and 500 or 600 on the concrete.

The Reader of the Paper Replies.—*The Lecturer*, in reply, said that Mr. Latham had referred to reinforced formulæ as being in rather a chaotic state. They had, indeed, certain formulæ to work on which they knew in a few years' time were likely to be modified or changed altogether. But, although formulæ changed, practice would not change very much, and the natural deduction was that though the present formulæ might not be ideal, they were not far outside the mark, and that for ordinary stresses they were not likely to lead them very far wrong.

Deterioration and Rusts.—To Mr. Latham's query as to whether he had accounted for deterioration and rusts, he would say that the formulæ were based on the workmanship being of absolutely the best character. In ordinary steel beams defects were to some extent allowed for by providing a factor of safety, but in reinforced concrete work, although they allowed a factor of safety, this did not take into consideration defects like the rusting of steel, which would destroy the connection between the rods and the concrete, and make the structure non-existent as a reinforced structure. Such defects could not be taken into consideration in any formulæ; the only way to avoid them was to make the work of the highest excellence.

Standard Symbols.—He quite agreed with Mr. Davidge, who had raised the question of the standardisation of symbols and formulæ, that it would be of enormous benefit if they could have a standard set of symbols, and if, later on, the institution should feel inclined to appoint a committee to forward such a movement, possibly in conjunction with other bodies, he thought some valuable results might be achieved.

QUANTITY SURVEYORS' ASSOCIATION.

REINFORCED CONCRETE, DESIGN, QUANTITIES AND PRACTICE.

Paper by Mr. MORITZ KAHN.

Mr. Moritz Kahn read a paper on "Reinforced Concrete, Design, Quantities, and Practice," before the members of the Quantity Surveyors' Association recently. Mr. Arnold E. Harris, J.P., F.S.I., presided.

Reinforced concrete, he said, when cast as a monolith, was more rigid than steel, and its strength in this respect partly accounted for the economy effected by its use. One need no longer doubt the strength of this type of construction, for in the hands of capable designers it was just as safe as structural steel work, with the additional advantage that its strength continually increased with age.

Limitations as to Economy.—In all important structures, and in all buildings where steel framing might be used, reinforced concrete would prove an economical structural material, but it was erroneous to say that reinforced concrete would always prove the cheapest method of construction. There were instances where it was not so cheap, and engineers soon recognised such cases. Middle-sized and small residential buildings, small manufacturing buildings, and the ordinary one-storey type of building would show very little saving when reinforced concrete was used in their construction. A low retaining wall 6 ft. high would be cheaper in brick than in reinforced concrete, inasmuch as it would require a comparatively thin brick wall to withstand the strain ; but a retaining wall over 10 ft. high could easily be constructed in reinforced concrete cheaper than in brick. Isolated girders and roof trusses high in the air would invariably prove cheaper in steel than in concrete ; but a steel structure, after having been built, would always require a certain amount of upkeep, and the maintenance charges thus entailed would have considerable influence on the total cost. Though the material under discussion might not always be the cheapest in first cost, it was generally the most economical, when all things were taken into consideration, such as the additional safeguard against fires, with a corre-

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sponding efficiency in one's plant, the saving in fire insurance premiums and the reduction in maintenance charges.

Components.—In the selection of materials the question was often asked whether preference should be given to crushed stone or ballast. Engineers were wont to object to the use of the latter on the ground that the surfaces were generally round and too smooth. It had often been demonstrated that round, smooth ballast gave just as strong a concrete as crushed stone. This statement might be qualified by the fact that in the early stages, say at the end of two weeks, crushed stone concrete would be found to be a little stronger than the ballast concrete; but at the end of 30 days ballast concrete was just as strong as stone concrete, and from that time on its strength began to surpass it. In the selection of this material, however, it was necessary to discover whether it contained chemicals deleterious to the cement. Sand taken from beds in contact with impure water killed the action of the cement, and should be condemned. Pit or bank sand was a very satisfactory kind to use. The cement should be of the very best grade, and should be subjected to repeated mechanical tests during the progress of the work. In this respect English cements were probably the best in the world. The handling and mixing of concrete was a feature which, to a great extent, governed its cost. Thus he advocated the use of machine mixers on large constructions.

Formulæ.—Regarding formulæ, he suggested that empirical formulæ should not now be used, for sufficient progress had been made in scientific research to establish definite results, and though various authors, who did not employ empirical formulæ, differed widely in their methods of calculation, it would be found that there was very little difference in the result, no matter what method was used.

Measurements.—As to measurement and pricing, the quantities of a reinforced concrete construction should be taken out in considerable detail. The cost of concrete in different portions of the structure varied considerably, and it was, therefore, desirable to know the yardage of concrete separately in footings, foundations, walls, columns, beams, girders, decking slab, and so on. The cost of centering varied in a similar manner. This should be measured up separately by the superficial area of the surface coming in contact with the concrete—namely, for walls, columns, beams, girders, decking slab, and so forth. Thus walls were measured both sides, without deducting doors and windows, as it was usual to let the form work run straight across these, unless it was impossible on account of mouldings, in which case the framing of the opening would cost as much as the form work omitted. Columns and beams should be measured by their girth, and decking slab by the horizontal measurements. No deductions should be made for the loss of area by the intersection of beams and girders, and small openings in the floor should not be deducted. Extra labour involved in belt courses, moulding, cornices, etc., should be measured by the lineal foot, giving the girth of same. All special features of exterior treatment should be carefully noted. The steel work should be taken off in pounds, and again the amounts used in the various constructions should be kept separately. One of the greatest sources of contention in reinforced concrete construction lay in the question of finish of the work, and therefore especial care should be taken to specify the kind of finish required and accurately to measure the surface area of the various kinds. If no particular finish was included in the contract for the reinforced concrete work, there should be a clause to the effect that all such work was to be left free from the centering. The upper surface of floors could either have a granolithic finish, screeded surface or surface left from the spade. If either of the first two was required, the yardage should be measured. There was, of course, no extra charge for leaving the floors with a spade finish. It was well known that the cost of materials and labour in different parts of the country vary to some degree, but it has been his experience that, in spite of the varying rates of wages and costs of material, the variations frequently offset each other so that the unit cost obtained in any one place might, generally speaking, be used for any other locality. There were, of course, exceptions to every rule, and in certain instances careful investigations should be made of special conditions, as the result of which one must use his judgment in either increasing or decreasing the unit rates by certain percentages.

Memoranda.—For general guidance the following figures of costs were given which had been taken from actual constructions, and included a net profit of about 10 per cent. to the contractor :—

COST OF COMPLETE BUILDINGS

Kind of Building.	Cost of Job. £	Unit Cost. Per Cubic Foot. d.	Unit Cost. Per Square Foot. s. d.
Offices and stores	36,239	6¾	8 0
Factory	2,555	5¾	7 0
Factory	7,066	6¼	6 6
Garage	2,078	4¼	5 0
Fire station	1,352	7¼	9 0
Store house	28,351	4¼	4 6
Cold storage building	40,010	6	5 0
Highest	—	7¼	9 0
Lowest	—	4¼	4 6
Average	—	5¾	6 5

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UNIT COSTS OF CONCRETE PER CUBIC FOOT.
Taken from an average of nine constructions.

	s.	d.
For footings and mass concrete	0	10
Walls below ground	1	0
Walls above ground level	1	2½
Columns	1	2½
Beams and girders	1	5
Flat slabs	1	3
Slabs between steel beams	1	1½

UNIT COSTS OF CENTERING PER YARD SUPER.
Taken from an average of nine constructions.

For footings and mass concrete	1	6
Walls below ground level	2	6
Walls above ground level	3	6
Columns	4	0
Beams and girders	4	6
Flat slabs	2	6
Slabs between steel beams	1	9

At the conclusion of the discussion which followed the reading of the paper,

Points.—Mr. Kahn replied to the various points raised. He said he was wholly against painting steel work in concrete. They were eliminating the fundamental principle of reinforced steel work when they did that. The theory was that the concrete binds with the steel, and if they painted the steel they obtained a sliding effect. That was with oil paint, for the result was quite different when the material was painted with cement. Steel work in reinforced concrete did not rust when it was coated with cement, owing to the chemical action set up.

Measurements.—As to measurements reinforced concrete work was new, and new problems were presented, and a great deal depended upon judgment. It was rather hard on the reinforced concrete contractor if they took out all little details, for it was difficult for him to price them, as he had had no experience. When the contractor saw that he was treated with fairness he made his price accordingly. Quantities for reinforced concrete should be taken out in the flat and not in detail. As to demolition, they presented some difficulties, for we build better than we knew. But reinforced concrete buildings could be altered much as structural buildings were altered, though the cost might be a little greater, because of the hardness of the material.

On the motion of Mr. H. T. A. Chidgey, seconded by Mr. A. J. Gate, Mr. Kahn was cordially thanked for his paper.

INSTITUTION OF MECHANICAL ENGINEERS.

REINFORCED CONCRETE.

Paper by Mr. ARTHUR C. AUDEN.

Mr. Arthur C. Auden, of Liverpool, read a paper on "Reinforced Concrete" before the members of the Institute of Mechanical Engineers at their recent meeting held at Liverpool. Mr. J. A. F. Aspinall, M.I.Mech.E., President, presided.

MATERIALS.

Generally.—An important point in connection with reinforced concrete frequently presented itself—namely, as to the nearest place where the materials, such as sand and gravel or chippings, could be obtained, and it was a question well worth close consideration, because in nearly all instances the cost of the proposed structure would be affected by the cost of its constituents, and these were in turn much influenced by the cost of freight and carriage. From this particular standpoint it was proposed briefly to classify the materials, as it was by no means uncommon to find that, within reasonable limits, one could by slightly altering the design, use cheaply obtained aggregates without in any way materially affecting the use and efficiency of the proposed structure, provided, of course, that the said structure was not of an ornamental design and did not contain much fine work.

From the above standpoint, therefore, the author would consider, firstly, the stone—that is, chippings or gravel.

Flints.—In many places in the Eastern Counties flint was practically the only stone locally obtainable, but though this made good, tough concrete, it was unreliable for fire-resisting purposes owing to its tendency to crack and "fly" under heat. The user, therefore, should balance his reduction in capital expenditure by a slight increase in his fire risk. It was interesting, however, to know that this tendency to crack under heat could be much reduced by passing all the stones through a crusher, as practically all flints had their crystallisation definitely bounded by planes along which they always broke, the remaining portions between such planes being comparatively homogeneous with but little tendency to "fly."

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Limestone.—The same remarks applied to limestone, but it had not the redeeming feature of being more fire-resisting after being broken : in fact, it was not advisable to be used at all where fire-resistance was an important consideration, as it was very apt to disintegrate to powder under the action of heat, but it was not to be condemned entirely as it was quite a serviceable material apart from increased fire risk. It must, however, be remembered that it almost always needed washing before use, as, after breaking, it would generally be found to be covered with fine, blunt dust which prevented the cement properly bonding with it ; the expense of washing would, therefore, be set against the cost of other slightly higher-priced stone which could be used as received.

Sandstone.—Sandstone could be obtained in many parts of the country in almost unlimited quantities ; but, as a rule, it was too soft, too porous, and too absorbent for use in reinforced concrete work. Samples should always be taken and tested by crushing, and if it was found that it would stand about 1½ tons per sq. in., and that the difference in weight, when clean and dry and after being two days under water, did not exceed 8 per cent. it could be safely used.

Quartzite Stone.—Quartzite stone was fairly good if not too soft and open in texture, in which case the same precautions applied as for sandstone.

With reference to testing for crushing strengths of either stone or concrete, it should be borne in mind that reliable results could not be readily obtained by crushing small pieces, say, of only about a square inch or so in area ; it was always advisable to use larger test pieces, say, such with an area of at least 10 or 12 sq. in.

Cheapness.—As they were considering the subject of aggregates from the standpoint of disadvantages *versus* cheapness, it was not necessary to allude to the numerous other stones which were quite suitable for reinforced concrete work, such as granite, basalt, millstone, grit, breccia, diorite, trap, etc., although there were inferior qualities of them all, but which, as a rule, it did not pay to use.

Artificial Aggregates.—With reference to what might be called artificially produced aggregates, broken earthenware and stoneware from the Potteries district made quite a good aggregate, but those who had not had experience with that material for reinforced concrete would be disappointed to learn that the same must be unglazed, thereby preventing the use of the many hundreds of tons of broken crockery now existing in some of the older Pottery towns, as the glaze prevented the proper adhesion of the cement, but doubtless that difficulty would be surmounted in time. When using unglazed earthenware, such as broken "saggers," care should be taken that the thick and thin pieces were, after being broken to pass the proper gauge, carefully mixed with each other, as a quantity of thin flat pieces together were apt to form beds or planes which were a source of weakness ; under any circumstances it was always better to mix some chippings or gravel with all broken earthenware.

Burnt Clay.—Burnt clay and gault were quite permissible materials, provided that they were tough and hard and did not soften or "crumble" after being left in the water for two or three days.

Broken Brick.—Speaking generally, broken bricks were not a good aggregate for reinforced concrete, although they had given excellent results in mass-concrete. They were usually too soft and yielded too much blunt dust and had frequently old mortar adhering to them ; if, however, they were hard and close in texture and free from mortar they might be safely used.

Coke Breeze.—It was well known that coke breeze made an excellent class of concrete, but it must be remembered that such could not be regarded as being really fireproof, although some recent tests by the British Fire Prevention Committee, to which reference would be made later, showed that that material could "hold its own" very well in that respect ; but from its nature it was much less capable of resisting either tensional or compressive stresses than harder and tougher materials, and the question of sulphur was also present. It was, however, quite possible to design a structure in such a way that—omitting the question of the best fire-resistance—a large portion of it could be made with reinforced concrete composed of this usually cheap and readily obtained aggregate.

Clinkers.—There were very few manufacturers or mechanical engineers who did not make ashes and clinkers, and many had to pay to have them removed. It was, however, quite possible, with care, to obtain two decidedly serviceable forms of aggregate from these, one being the ashes, which were very similar to coke breeze, and the other the hard-burnt clinker ; but as with all other materials except the real stone aggregates before mentioned, discretion must be used in the selection of any which were derived from waste products, such as were now under consideration.

Ashes.—In the case of ashes, only those that would float in water and which were of a uniform colour and texture, and quite free from adhering pieces of coal and dirt, should be used, while with clinker only that which was really hard and clean was serviceable. In both cases, if the washing and riddling or screening were carried out as one process, a more reliable result would be obtained. The question of sulphur must, however, be carefully watched.

Slag.—Slag from furnaces, whether blast or cupola, made also quite a good aggregate, provided it was hard and tough and free from dust, and its sulphur contents carefully noted.

Sulphur.—As was well known, all clinkers, breeze, slags, etc., contained a certain amount of sulphur which was apt to attack the reinforcing steel with disastrous results. The maximum allowable percentage

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of sulphur in reinforced concrete aggregates was now being made the subject of tests and experiments—as in fact were all other details in connection with reinforced concrete— and it was to be hoped that an authoritative statement on the subject would shortly be issued, as it was of considerable importance to engineers, particularly to those who had slag heaps of any considerable size, but there was an important point in connection with the presence of sulphur—namely, that if it was in the form of "sulphate" it was practically harmless, but if in the form of "sulphide" it was very deleterious, and anything more than a very small amount indeed should not be allowed.

Free Lime.—Care should also be taken with all artificial aggregates that no free lime was present; but, as in the case of sulphur, there were two forms of this material present, one the free lime referred to, which was dangerous, and the other carbonate of lime, which was practically harmless. It must be noted, however, that washing and exposure to the air and sun would do much to convert the dangerous sulphide into the comparatively harmless sulphate, and exactly the same was true with reference to the harmful free lime and its practically safe carbonate. Unfortunately, quite good and accessible aggregates containing lime or sulphur were sometimes condemned *en masse*, because no discretion was exercised as to the form in which such occurred.

Washing and Screening.—Mention had already been made of the washing and screening of aggregates, and it might be of interest to note that "jigging" was a much better method than throwing against an inclined sieve or screen; it had the advantage also of enabling the washing to be done simultaneously with the screening, and also—particularly in the case of the artificial aggregates—jigging knocked the weak corners off and produced better shaped pieces.

Fire Resistance.—Before leaving the subject of aggregates, the author drew attention to the recent important fire tests made by the British Fire Prevention Committee, of concrete composed of various descriptions of material, the proportion of cement, sand, and aggregate being identical in each case—*i.e.*, 1-2-3, except with the burnt clay and coke breeze where there was no sand, the proportion being 1-0-5.

Sand.—Sand was, in some parts of the country, more difficult to obtain than any other constituent of reinforced concrete. A certain amount was absolutely necessary, and nothing up to the present was known which really and entirely supplied its place. Engineers having foundries would have a ready means of judging sand for reinforced concrete if they remembered that, generally speaking, the better sand was for moulding, the worse it was for reinforced concrete. For instance, it must not "bind"—that is, retain any shape when compressed—and it must be incapable of being smoothed with a trowel to a bright surface, or of "standing up" by itself when cut with a shovel, these being "rough-and-ready" methods of ascertaining that the sand had what was required—namely, large sharp grains. Dirt in the form of slime, mud, or vegetable refuse was distinctly bad, but a little loam, enough to soil the fingers when lightly rubbing the sand between them, but not enough to make the sand itself adhere to them, was no detriment. Small particles or nodules of clay did not appear to affect the strength of the concrete provided they were very small both in themselves and in number, but they were not an advisable ingredient, and should be avoided if possible, unless there was ample time to mature and test sample pieces of concrete made with the sand containing them.

If sand was scarce or costly, some economy might be effected by regarding the very small pieces of the stone or other aggregate, below ¼-in. mesh, as sand, and mixing them with some real sand. The economy was not so apparent as appeared at first, because the small pieces must be screened out from the larger aggregate, and in most instances washed to remove the floury dust before being mixed with the real sand, ready for putting in the gauge boxes. It was not good practice to use the stone aggregate and its smalls and dust and some sand upon the chance that they would be in the proper proportions and that the voids and spaces would be properly filled. Experience had shown that this was usually not the case, and although that frequently was the practice with mass-concrete it should not be allowed in reinforced work where absolute homogeneity was so essential.

Cement.—With reference to cement there was nothing to remark here, as most excellent descriptions of that material were obtainable anywhere, but it should not be one of the many mixtures imported into this country as *cement*, which did not deserve the name, and were costly at any price. Any user was safe if he insisted that his cement should pass the British Standard Specification in every detail, and that it was purchased from a reliable manufacturer.

REINFORCEMENT.

Generally.—It was important that all reinforcement should be so designed as to possess a considerable amount of initial rigidity, so that it did not "sag," or "warp," or "twist" when placed in position in the mould boxes. Many illustrations regarding this could be quoted, but that of compression bars intended to be above the neutral axis in a beam, sagging down by their own weight till a portion of their length was below the said axis, where it was worse than useless, was not by any means as rare as it should be. The same remarks applied to lateral misplacement, particularly in the case of columns and struts, as well as to the pitching and spacing of reinforcing bars or metal on

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flat surfaces, such as floors, walls, etc. In those last mentioned it was practically essential to have the bars or metal so designed that it could not be knocked out of place, as it was almost impossible to keep a number of separate loose bars in proper pitch. It was advisable, therefore, that all reinforcement for this form of work be woven together.

Punching or slitting solid plates into strips or bars was another efficient form of reinforcement for flat surfaces, particularly for those which were approximately square in plan—viz., where the strains were practically equal all over; but for flats, where the length was considerably greater than the span, a wire meshing was cheaper, as the cross-span wires took the load, the longitudinal ones being only necessary to keep the others in pitch, and it was not advisable to pay for metal and strength in the longitudinal direction where it was not wanted.

Auxiliary Tension Members in Beams and Slabs.—An examination of all the accepted specifications, for the last ten years, dealing with reinforcement, or a reference to the advertisement pages of technical journals, would show that it was almost universally acknowledged that those important accessories must be inclined to the main tension-bars and *not* be at right angles thereto, and also that such bars must be so designed as to retain absolutely their positions where they were connected to the main tension-bars and could not be slipped or moved along the same when ramming the concrete or otherwise. It was not such good practice, though frequently exceedingly convenient, to obtain auxiliary tension members by means of placing a large number of rods or bars in the bottom of the beam and bending up the ends of them at various points, although by this means the desirable inclination above mentioned was gained, but this design involved a considerable excess of metal at the centre of the beam, and a greater weight of steel than was required must be purchased.

Reinforcement of Struts and Columns.—There were two very distinct methods of reinforcement in use for these, one being that in which the vertical bars were prevented from spreading by being spirally wound with rods or wire, and the other where the same end was obtained by means of rings or loops of wire tying the vertical bars together, such loops or rings being arranged at various distances apart to suit the design and strength desired. Both those methods had good and bad points, each one being the best under appropriate conditions.

Spiral Winding.—The spiral winding had given most excellent results, and was considered by many to be the best for columns, etc., as it permitted the use of lighter and fewer vertical rods, but it had the disadvantage of being somewhat difficult to make it a "good mechanical job"—that is, so that the spirals should all be the same diameter and parallel in bore, otherwise some would clasp the group of vertical bars too closely and others hardly touch them, which resulted in unequal stresses. This was, however, generally made much easier by using bands of flat rectangular section which bend readily, and by first winding the spirals on a cylinder and then slipping them over the vertical bars when made. Great care should be taken when using spiral reinforcement in vertical columns that it was not made in too long lengths, as all the concrete had to be put in from the top of each length, and it was well known that when concrete was dropped from even a small height the mixture of its constituents became very uncertain. Care should also be taken that each length of spiral was "corkscrewed" well into the one below it, as otherwise there was a plane of weakness between each length of spiral. This form of reinforcement should be so designed that the required strength was obtained without the pitch of the spiral being closer together than the size of the largest pieces of aggregate used, as if it was so the stones became jammed between the coils and a lack of homogeneity was the result.

Loops or Rings.—The second method of column and strut reinforcement above mentioned—namely, loops or rings slipped over the vertical bars and held at the proper distance apart—was also an excellent one, especially when the loops were carefully made mechanically on hard metal formers, so that each one was an exact replica of its neighbour, the result being that each one equally clasped the group of vertical bars, otherwise should one be tight and the other slack the bursting strains would not be taken up by all the loops in equal proportions. As the first desideratum of this design of column and strut reinforcement was the prevention of the vertical rods spreading apart under the load (the loops themselves, being further apart, did not resist the bursting strains on the concrete to the same extent as the spiral windings), it was not good practice to allow the loops to be curved in between the points where they touched the vertical bars. Unless the wire or rodding forming the loop was straight between its resistance points it did not get a chance to develop its tensional strength, as it must "pull itself straight" first, which it did at a low stress. For this reason the use of comparatively high-carbon steel was often recommended for columns or strut loops, as it was stiffer to resist distortion, and as distortion was one of the main things to avoid, particularly in that phase of reinforcement, the use of harder steel, if the same could be obtained without any marked increase in cost, appeared to be certainly indicated; in fact, as the elastic limit of all reinforcement was almost of as great importance as its ultimate strength, the use of bars and rods possessing considerable resistance to stretching was certainly to be recommended, provided that the

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said ultimate strength was not appreciably decreased. The use of high-carbon steels had been recommended for various other reasons.*

Reinforced Rods.—It is often said that it was immaterial whether the reinforcing rods were bent or not, as, being bedded in concrete, they were immovable, and doubtless that might be true in a structure where there was no vibration and where the loads were unvarying in amount and disposition; but where it was not so there was a tendency on the part of the concrete on the concave side of the curved pieces of wire or rodding to become friable, and that tendency should be eliminated in the design by working the reinforcement in straight lines whenever possible. It should also be noted that all the joints of the vertical rods in columns and struts must be in close-fitting sleeves—preferably of good quality lap-welded steam barrel.

Designing Reinforcement.—When designing reinforcement there were, of course, many points for consideration quite irrespective of the particular method of constructing or attaching the various parts or members, one of the principal being that all beams or floors running continuously over the tops of columns or stanchions or walls must be reinforced above their neutral axis where they passed over the said columns, in exactly the same way as they were reinforced below that axis in their clear span, as the parts in tension and compression were reversed in those circumstances. In one well-known system the bars were run along both top and bottom surfaces from end to end, but those rods or bars in the compression area were only provided as a means of keeping the shear-members or loops or stirrups in position, not as reinforcement against reverse flexure, nor as such in compression, this last not being needed unless the area above the neutral axis was such that it could not stand the allowable crushing stress.

The exact position of this neutral transverse—or, more correctly speaking, diagonal—plane of "reverse flexure" had not so far been very exactly located, and it will, of course, vary with every variation in the distribution of the load. The present practice was therefore to design the reinforcement over the supports, to overlap the ends of that which runs along the "belly" of the beam. The diagonal auxiliary shear-members connected to each of the main tension-bars above and below the neutral axis thus became parallel to each other in the same way as the tension members in a lattice girder. The same arrangement must be carried out where the ends of beams rest on and in walls.

Designing Beams.—When designing long and deep beams or girders, such as for a railway bridge with flat (not arched) spans, it would also, not infrequently, be found that the available area of concrete in compression above the neutral axis was such that the stress per square inch was more than the concrete would safely stand—that is, more than 550 to 750 lb. per sq. in. according to the class of concrete and the nature of the aggregate used; but this was easily overcome by using reinforcement in the compression area, always remembering that the value of steel in compression was 50 per cent. less than that of the same in tension. Here also the question of rigidity to resist deformation under compression was important, exactly as it was in columns and struts, and care should be taken that all the separate members in compression were properly braced together to avoid the tendency to spread in any direction, but particularly sideways and downwards. Even with ordinary beams supporting floors the question of the available area of concrete in compression demanded consideration; but the floor and beam being all in one solid piece not only did the part of the floor immediately over the beam contribute to the desired area, but portions of the floor on each side of this were available also, thus enabling them to regard the beams as of T section; but, except under special conditions of loading, the breadth of floor which they could consider for the purpose of this calculation should not exceed four to six times the breadth of the beam itself, according to the class of concrete and the nature of the aggregate used. But even with this reservation the fact of the beams and floors being solid together enabled a wonderfully strong and light structure to be obtained.

Temperature Stresses.—Another point to be remembered was that temperature stresses must be carefully guarded against, and that extra reinforcement, in fact, increased scantlings over all, must frequently be adopted for that purpose, as the coefficient of expansion of steel and of concrete was practically the same. In structures such as bridges those variations due to the temperature could be arranged for by the ordinary hinges or expansion joints (of which the latter could be very rapidly and effectively made with thick sheet lead, the area being such that no pressure it would experience would cause it to "squeeze out"), but in the case of structures where such were impossible, as, for instance, in an exposed tank or bunker or silo, the only remedy appeared to be a general increase in strength, particularly by means of increased reinforcement, and, although perhaps contrary to theory, that method had proved perfectly successful.

* Mr. Charles F. Marsh, M.Inst.C.E., in a paper read before the Concrete Institute, stated that for hooped members, if the allowable compressive stress in the concrete was higher than about 1,000 lb. per sq. in., it was advisable to use high-carbon steel for the longitudinal reinforcements, and the employment of high-carbon steel for the bindings was always advisable.

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DISCUSSION.

Sulphur, etc.—*Mr. E. Spencer Bourne* said that with regard to sulphur in the form of sulphides, which the author said should be avoided under all circumstances, he wished to ask whether the action of sulphides was as bad as was often supposed. The reinforcement was practically hermetically sealed within the concrete, and he thought probably the action of the sulphide was therefore not so deleterious as it was often thought to be. Mr. Auden, in his remarks on cement, said that any user was safe if he insisted on the cement passing the British Standard Specification, and purchased from a reliable manufacturer. He wished to add a further remark in that connection to the effect that it should be properly stored before use. This was most important in order to avoid initial hydration. He, however, had known instances of men purchasing expensive cements, and then paying less attention to their proper storage than to the storage of ordinary timber.

Sand.—*Mr. Priest* considered that the most interesting part of the paper was that relating to the quality of the sand. The author stated that the sand should be sharp. That was a time-honoured expression, and he had used it himself for twenty-five years, but had finally discarded it as unsatisfactory. The word "sharp" conveyed the impression that under a powerful glass the sand should appear like broken macadam. As a matter of fact such a sand did not exist. It was all rounded, and this really seemed to be all that was necessary for the purpose. Angular forms presented no advantage, for actually when cement was formed it was not a mixture, but a combination, and this combination was complete so long as the surfaces of the grains were clean, and not protected by a slimy coating. Again, he considered it not necessary that the sand should be absolutely clean any more than it should be sharp He had made innumerable experiments which proved that up to a certain point, at any rate, the strength of the mixture increased with the percentage of dirt. It was common practice in testing to use some standard sand, and while this at twenty-eight days gave a test higher than dirty sands, he found that at six months nearly every one of the latter with which he had experimented gave a better result, the standard sand specimens at that period showing up the poorest of the whole lot. He had, for instance, tried a 15 per cent. loamy pit sand, made up in a 3 : 1 mixture. This gave a result 20 per cent. better than the tests with sand free from loam, and he thought that his experience showed that with anything up to 22 per cent. loam in the sand the results would be as good, and better, than clean sand. Beyond this percentage the strength began to fall off.

The best sand he had tried was that produced from crushed red sandstone. This gave much better results than standard or pit sands, and in a 3 : 1 mixture the results had been so good as to lead him to think that at two or three years the results might be just as good as pure cement.

Supervision.—*Mr. B. Ellington* remarked that his experience had extended to the use of reinforced concrete for reservoirs, floors, roadways, etc. This experience had impressed upon him the fact that, apart from the selection of material and method of work, etc., the most important matter on which the success of this class of work depended was that of supervision.

General.—*Prof. W. C. Unwin* pointed out that the good results were wholly dependent upon the care and skill with which the work was done, and on the workmen carrying out the correct placing of the members. Without this care serious accidents must ensue, and every precaution should be taken to see that the intended arrangement was actually carried out. The system was dependent on the concrete satisfactorily taking the place of riveting in ordinary work. The Committee appointed by the Institution of Civil Engineers had already collected a great deal of information, and from this it would appear that reinforced concrete work had been, on the whole, well done in the past. There had been, it was true, a few disasters here and there from bad design or workmanship. It must be admitted that up to the present guess-work methods had prevailed more or less. For instance, he would draw attention in the paper to the case mentioned in which girders supported a floor, and the whole construction was made monolithic. The author said that, in calculations for compression, the breadth of floor, considered in connection with the beam, should not exceed from four to six times the width of the beam. These figures were themselves proof, he thought, of the employment of a certain amount of guess work, and there was thus an uncertainty as to the exact factor of safety that was being provided until fuller information was available. One thing he remarked about the paper, and that was that there was no reference in it to any of the multitude of patented designs and systems of which so much was commonly heard.

Anchorage.—*Mr. W. H. Maw* considered that the difficulties attendant upon providing for the end of a beam resting in an ordinary wall, an anchorage such as would entitle that beam to be regarded as a continuous girder, were very frequently under-estimated. When a girder was carried over a line of columns, it was quite easy to adopt such a design as to secure the advantages of continuity, although in practice it would generally be found that, from an economic point of view, such advantages were much less than theory might lead one to expect. In the case of a girder resting at one end on a column and at the other end in a wall, however, the circumstances were different, and it would usually be found that in the case of ordinary warehouse walls the cost of securing a proper anchorage would outweigh any saving due to continuity of the girder. It was convenient to remember that in order to entitle

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a girder to be regarded as "continuous" the anchorage in the wall must be such that if applied to a cantilever one-fourth the length of the girder, it would permit that cantilever to carry at its end a load equal to three-eighths of the distributed load on the girder. Thus in the case of a girder 20-ft. span carrying a load of 2 tons per ft. run, the anchorage required at the wall end must be such as would suffice for a cantilever 5 ft. long, of the same depth as the girder, and carrying at the outer end a load of 15 tons. Such an anchorage was, as he had said, very difficult to secure in an ordinary warehouse wall; and if the wall were pierced by window openings, it became practically impossible, except at a very high cost. Altogether he considered it undesirable that in lines of girders the spans extending from columns to the walls should be regarded as continuous.

Piles.—*Mr. Graham Harris* thought one of the most interesting and peculiar uses of reinforced concrete was its employment for pile work. He had used 60-ft. piles of reinforced concrete to get through wet soil to gravel below in places where the piles at the first drop went into the ground to a depth of 14 ft. They had used the ordinary point, and the piles were made on end in vertical three-sided troughs. The vertical rods were ¾ in., and slip-rings and wire loops held them in position at regular intervals. In the making, these were strung up overhead out of the way until needed. The front of the case was gradually carried up as the work proceeded in stages the width of a 12-in. board. In this way the casing was gradually filled and every bit of concrete was punned down.

Something like 2,000 piles had been so constructed on work with which he was connected, and they had been driven easily and satisfactorily. At first they had attempted to drive with an ordinary 2-ton monkey, but this they soon found shattered the tops badly. A wooden dolly was then tried on the top of the pile, but without satisfactory results. They finally used a cast-iron arrangement, which resembled two cups placed base to base. The inverted cup was placed over the pile-head with, inside it, a cushion made of sacks of sawdust. Sacks of sawdust were also placed in the upper cup, and on these a block of wood, and this cushioning protected the pile very effectively.

Supervision.—*Mr. F. G. Badger* considered efficient supervision of prime importance. Later on it might be that workmen would come to understand sufficient of the underlying principles to take greater care in the work of their own initiative. He noticed that for joints in vertical rods sleeves were advised. In Liverpool, sleeves were, as a matter of fact, insisted on, and he agreed that they were good, and would probably stand in the regulations until the Committee was convinced of something better.

He saw no reason why the main girders, the cross-bearers, etc., of a reinforced concrete bridge should not be made in the builders' yards, and handled, when finished, in much the same way as plate girders and the component parts of bridges were constructed in the builders' yards to-day, and removed and re-erected on the spot. He looked forward to the ultimate replacement of all plate and girder railway bridges by bridges of reinforced concrete in some such manner as that, and the consequent material reduction in the heavy cost of upkeep. There were many uses on railways to which concrete might be put with advantage.

The Reader of the Paper Replies.—*The Lecturer*, in his reply, pointed out that many advantages accrued from the use of concrete. In building, for instance, it was much easier to haul up to a given height a small bag of cement or buckets of concrete than it was to handle large steel work and other constructions needing heavy cranes and other appliances.

Sand.—In view of Mr. Priest's remarks on dirty sand, the author felt that he might have safely said more with regard to his own experience than he had done in the paper. His experience was confirmed in this respect by Mr. Priest, and he had only put his case in a very mild form because he had found that he had before now horrified people when he had spoken of there being no harm in permitting 2 per cent. of dirt. As a matter of fact, with 10 per cent. he had had very good results at three months; but he had never tried as high as the 22 per cent. mentioned by Mr. Priest.

Red sandstone sand, as far as his experience went, gave fair average results, and nothing exceptionally good. After Mr. Priest's remarks, he would, however, be inclined to test this sand more thoroughly than he had done hitherto. He quite agreed that the sand component should be in all senses the complement of the cement, and that the future would probably reveal economies possible in this as in other directions.

Deterioration.—With regard to deterioration he would recall the fact that when some years ago the old Brighton pier was blown down, chains had been found in the work which must have been placed there about 115 years before, and they were about as clean as when they left the forge. Similarly, in the Spanish ore-mines worked 2,000 years ago by the Romans, there had been found embedded in lime lias cement old pick-heads and other implements bright and clean. If kept away from water, the reinforcing material would keep perfectly well.

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NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

CONCRETE GARDEN VASES.

In connection with the ornamentation of gardens with vases, statuary, etc., of the type shown in the illustrations herewith of work executed by the Garden Studio of Boston, a well-known landscape architect, Loring Underwood, in "The Garden and Its Accessories," makes the following statement:

"The appreciation of well-designed garden accessories, which may be had at a reasonable cost, has led architects to try various materials, and of these concrete seems to have proven itself the best. We are beginning to realise that cement has, in addition to its value for structural purposes, possibilities hitherto undreamt of for development along artistic lines. There are many good reasons for using this material in gardens in preference to marble or stone. In the first place, it has the lasting qualities of flint. In fact, it grows harder year by year. Then, too, it does not need any protection against the severest weather, freezing and thawing having no effect upon its rigidity. The colour of this material in its natural grey cement shade is most pleasing, and seems to blend with out-of-door surroundings in a way which marble or newly-cut stone does not. It takes on rapidly the soft neutral colour of the common field stone, and, when made into some accessory of pleasing design, never seems to look out of place, as is often the case with imported marbles. Again, the cost of this material is reasonable. Concrete can be fashioned readily into any form, just as plaster and bronze take on the form of the mould into which they are run.

CONCRETE BALUSTRADE VASE.

"Some concrete is liable to form hair-cracks, or crazing cracks, on the surface soon after it is exposed to the weather; but these do not imperil the strength of the material. They are fine cracks, hardly the size of a hair, both in depth and breadth. They are not a drawback to a garden-piece, but rather seem to give it a look of age.

"There is no excuse for attempting to make concrete appear what it is not. The writer feels that he cannot insist too strongly on this point. Some attempts have been made to fashion concrete so as to imitate natural and rock-faced stone, but the results have been, for the most part, only pathetic. A horrible example of the abuse of cement is the block moulded in a wretched attempt to imitate rock-faced stone. Frequently these blocks appear of the colour and texture of dried mud, the surface

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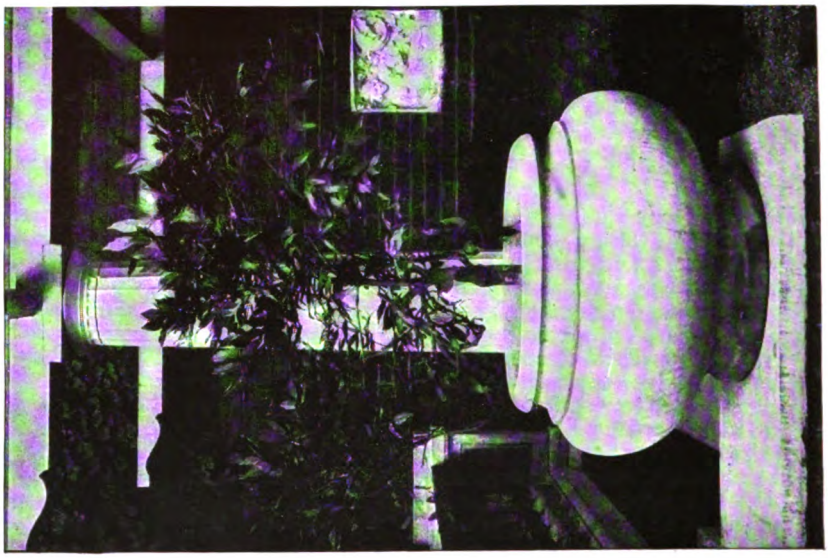
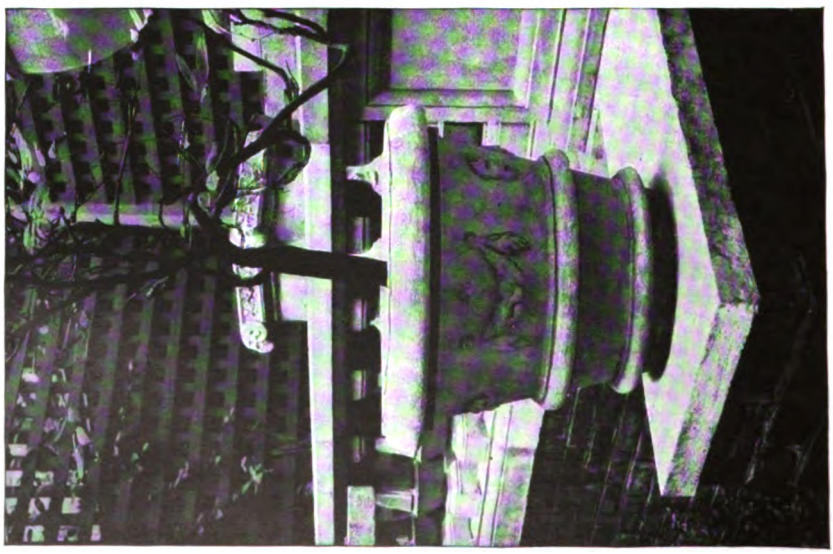
having the appearance of having been rubbed with a wet hand, and left utterly devoid of all life and sparkle. To such work as this is due the blame for the impression that cement lacks all possibilities for artistic manipulation.

"The appearance of the unfinished side or interior of these same blocks bears





CONCRETE GARDEN VASES.

witness to the fact that cement does possess the very qualities which have been covered up on the exposed surface, colour and texture."

We are presenting the illustrations by courtesy of our American contemporary the *Cement Age*.

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED

WAREHOUSE AT LIVERPOOL.

On the accompanying pages will be found photographs and drawings of the extensive warehouse premises at Islington, Liverpool, built for Messrs. Baxendale Bros., of Liverpool, to the designs of Mr. T. Myddelton Shallcross, architect, of Liverpool.

We understand that the structural steel work and reinforced concrete flooring, roofing, dome, stairs, etc., were designed and constructed by the Expanded Metal Co., Ltd., the former being obtained from Messrs. Redpath, Brown and Co., Ltd., at their Manchester works.

The exterior walls are of red brick with stone facings, and the building has a mean length of 165 ft. with a width of 75 ft. and a height of 50 ft.

The building comprises a basement and three concrete floors and a roof reinforced with expanded metal; there is also an interesting dome over the circular stair well at the main entrance similarly reinforced.

As to the structural details the following are the particulars :—

The three suspended floors and the roof are carried by structural steel work built up of rolled sections, the flat roof being used for storage purposes. The columns are composed of a 10-in. x 6-in. x 42 lbs. H section with 2 12-in. x ½-in. and 2 12-in. x ⅜-in. plates for first floor length, 2 12-in. x ½-in. plates for second floor length, 2 10-in. x ⅜-in. plates for third floor length, the 10 in. x 6 in. being carried up to roof level without plates.

The flooring and roofing was designed to carry 2½ cwts. per ft. super. and is continuous over intermediate bearings, the concrete being haunched down to the bottom flange of the joists, the bottom flange being encased in expanded metal and the soffit of the flooring and roofing is finished in gauged plaster.

The flooring is 5½ in. in total thickness, 2½ in. coming over the top of the mains and joists, which are level on top, and is reinforced with No. 61 3-in. mesh expanded metal in the intermediate bays and with No. 62 3-in. mesh expanded metal in the end bays, the concrete being composed of four parts ¾-in. and down Welsh granite chippings with not less than 30 per cent. of fine stuff in its measure to one part of J. B. White's Bros. Brand of Portland cement, the top ¾-in. of facing being Scotch granite fine chippings and white sand and J. B. White's Bros. Brand of Portland cement 2½ to 1 finished from the trowel and laid while the concrete was green, so that the whole should be monolithic.

The roofing is constructed on similar lines to the flooring, but is laid to fall for drainage and covered with asphalt for waterproofing purposes, built to the same details as the flooring to allow of future extensions.

The main circular stair well forms an important architectural feature of the building, and is supported by eight R.S.J. stanchions encased in brickwork; the stairs, landings, etc., being carried on R.S.J. stringers with steps formed in expanded steel concrete. There is also a back staircase carried on R.S.J. stanchions and stringers with steps formed in the same manner.

The piers supporting the main circular stairs also carry the dome referred to, over the stair well, the dome being 25 ft. 6 in. dia. by 8 ft. 8 in. high inside dimensions.

It should be mentioned that the columns were not encased in concrete, but were simply painted. For owners of an important structure such as this one, where the

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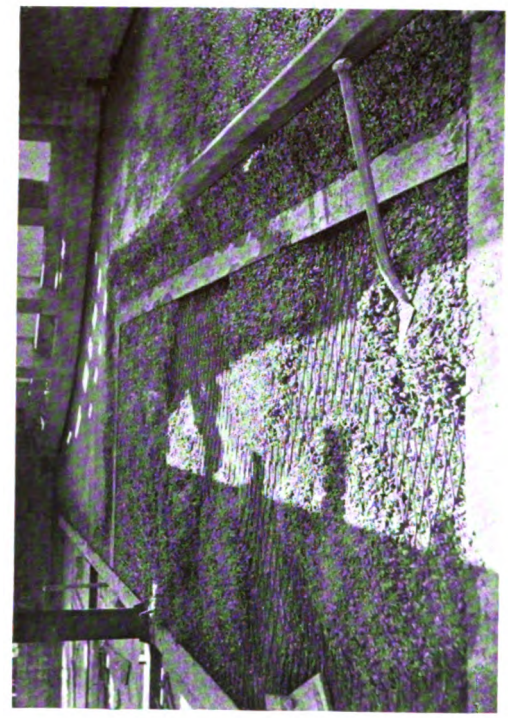

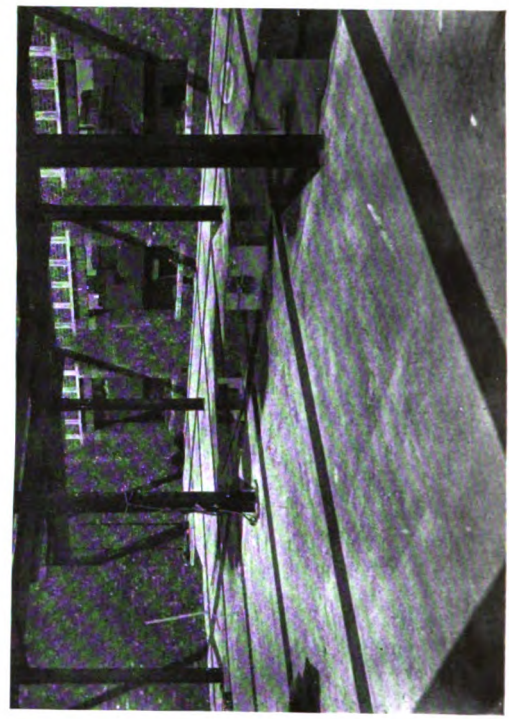

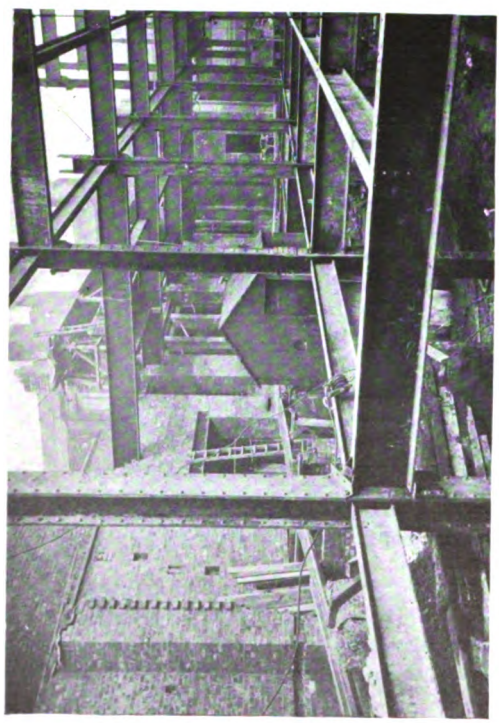

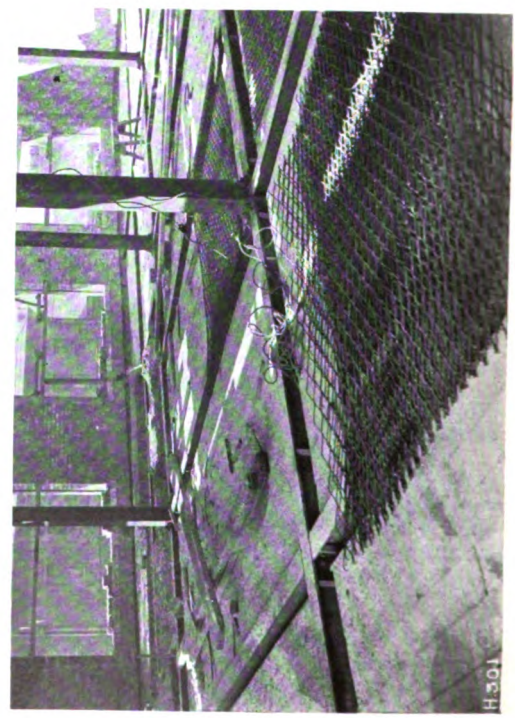

CONCRETE AT MESSRS. BAXENDALE'S WAREHOUSE, LIVERPOOL.
(Showing concrete floor reinforced with Expanded Metal in course of construction.)

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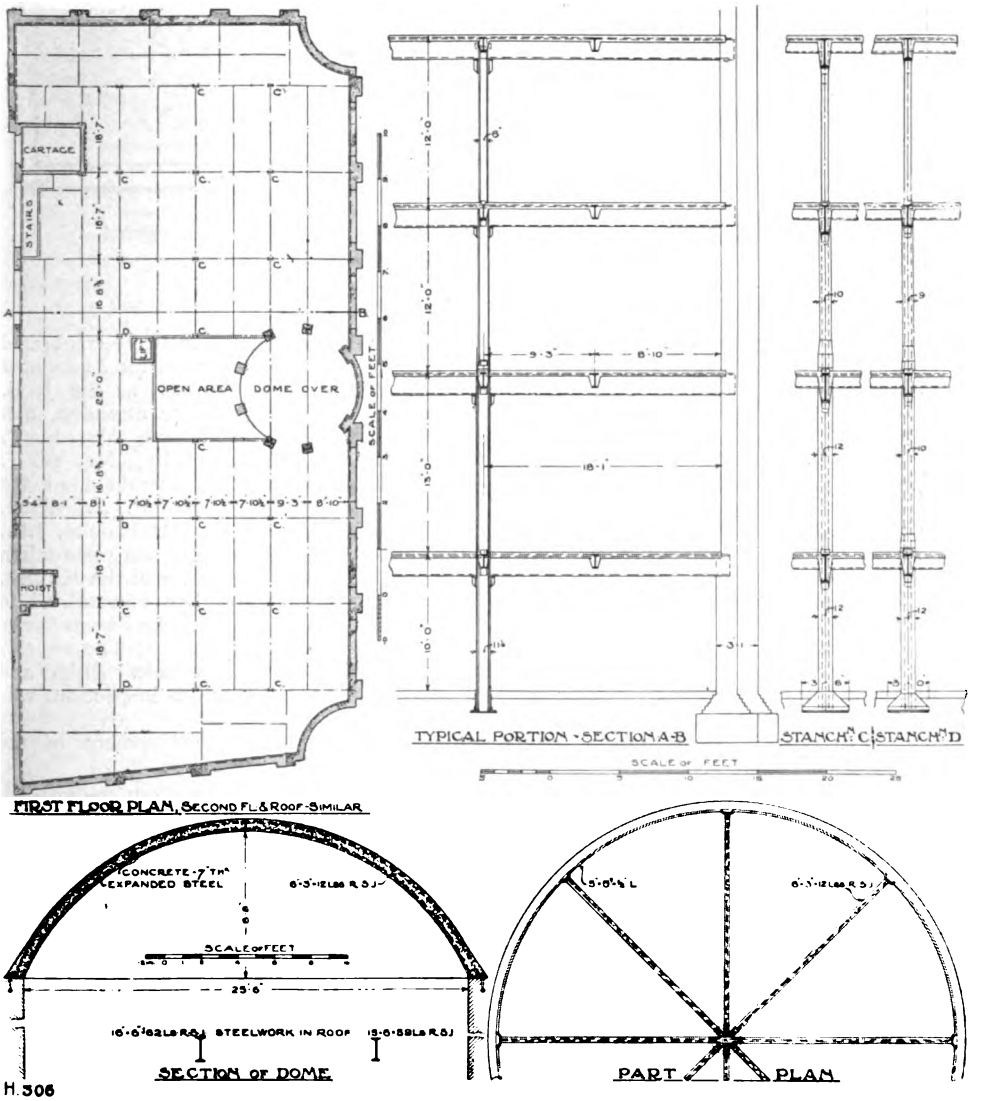
loss and inconvenience of a fire would no doubt be considerable, to ignore the expense of properly encasing and protecting the vertical supports to the fire-resisting floors and roof is one of those entirely incomprehensible instances of out-of-date building con-



MESSRS. BAXENDALE'S WAREHOUSE AT LIVERPOOL.

struction still, unfortunately, often met with. It will only require a moderate fire of sufficient temperature to affect the unprotected steel stanchions in order to let down the well-conceived and efficiently constructed floors which are such an excellent feature in this structure.

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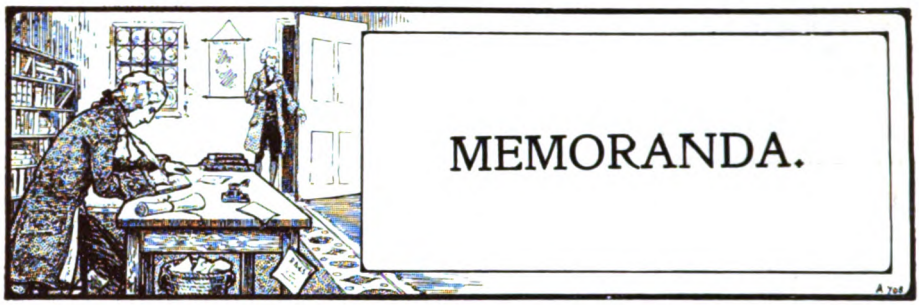

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

VISIT.

The Concrete Institute's First Anniversary.—The Concrete Institute celebrated its first anniversary by a visit to the Swanscombe branch of the works of the Associated Portland Cement Manufacturers, Ltd., near Gravesend, better known as the J. B. White Bros. branch. About one hundred members of the Institute attended, and among the party were Mr. Edwin O. Sachs, F.R.S.Ed. (chairman), Mr. E. P. Wells, J.P. (hon. treasurer), Mr. C. H. Colson, M.Inst.C.E. (Admiralty), Mr. W. T. Hatch, M.Inst.C.E. (Met. Asylums Board), and Mr. J. Munro, members of the Council. The visitors were met at Cannon Street Station by Mr. F. A. White, chairman of the company, and by Mr. H. H. D. Anderson, Mr. Herbert Brooks, J.P., Mr H. K. G. Bamber, F.C.S., Mr. Alfred Stevens, and other directors, and were taken in saloon carriages to Northfleet Station, from which the chalk quarries of the Knight, Bevan and Sturge branch were seen in operation. They were then entertained to luncheon at the Factory Club and afterwards driven by special trams to the Swanscombe Works, which contain the largest installation of rotary kilns in Europe. The visitors went over the works in eight groups, each group being under a technical guide and a director of the company; thus a most thorough and instructive inspection was assured. Afterwards they were entertained to tea.

Mr. White, in welcoming the party, dwelt on the rapid development of the Concrete Institute into one of the most important institutions.

He imagined that the membership of the Institute, and therefore their guests to-day, comprised four sections—architects, engineers, some rival cement manufacturers, and concrete specialists.

The first two classes were those upon whom they depended primarily for fostering reinforced concrete construction, which was the new feature in building operations that marked the close of the nineteenth and the beginning of the twentieth century. He thought there was very little doubt that this method of construction was no passing phase, but that it had come to stay, and he could well understand the interest that the professions felt in making themselves acquainted with the manufacture of the cement which played so important a part in it.

With regard to rival manufacturers, it might seem strange to some that they should invite any of them to visit their works. No doubt they (the A.P.C.M.), like other people, must think of their own interests, and it might fairly be held that these did not comprise the showing of their works to those who were in competition with them. On the other hand, there was a larger and broader view, and they were inclined to take that, for they believed that the good of all was the good of each, and that not only was it important that each of them should prosper, but it was also very important to that end that the cement trade of England should bear favourable comparison with the cement trade of other countries. This could only be if the best methods were generally followed, so that as a trade they might be in the best position to face the competition of the world. At all events, they determined not to exclude these gentlemen, with whom personally they had friendly relations, from the visit that day, but rather to include them in a cordial welcome.

There remained the concrete specialists, and they were very glad to receive them, because they regarded their position as a necessary one in what they might call a new industry, and they were glad to afford them an opportunity of satisfying themselves that they could rely on the best material for their important works.

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Mr. Edwin O. Sachs (Chairman of the Executive), responding on behalf of the Concrete Institute, expressed the thanks of the members for the very courteous invitation.

The members not only appreciated being shown the works, but they also appreciated the excellent arrangements made for their convenience and the hospitality accorded them. Mr. Sachs pointed out, however, that what had most impressed the Council of the Institute when the invitation was tendered was that no exception had been made, the invitation including all the members and subscribers of the Institute, notwithstanding the fact that some of these were directors, managers, and chemists of other cement works and rivals of the Institute's hosts. He considered that this was a broadminded way of not only advancing knowledge regarding cement making, but of advancing the national importance of the cement industry, for it showed that the Associated Portland Cement Manufacturers took no narrow view of their business, but realised that if they were to prosper—as they deserved to do—the whole of the industry of the United Kingdom should also prosper, and the standing of that industry as a whole in the highest technical professions, both at home and abroad, must be of the very best and in the van of progress. He trusted that their hosts' competitors—of whom he understood some ten were present—would appreciate not only the courtesy extended to them, which in a way was quite unique, but also realise the necessity of harmony where a leading industry was concerned.

As to the works of the Associated Portland Cement Manufacturers, he thought that all those present had long realised that their hosts had a gift for organisation and thoroughness which made for good workmanship and the production of a first-class product. Thoroughness and reliability based on science and experience were the essence of cement making, and the architect and engineer naturally accorded the greatest possible confidence to those firms who in their management, in their business dealings, and in their general policy gave evidence of thoroughness, power of organisation, and broadmindedness.

There was only one other point he would like to touch upon on this occasion, and that was the extraordinary mania for cheapness which was prevalent throughout the country, to the detriment of the prosperity of numerous industries, including the Portland cement industry. It was obvious that we purchased and enjoyed many things too cheaply, and it seemed to him ridiculous that so much effort should be applied to cement making in the country and so much capital invested in it without there being a reasonable and moderate return for that effort and the money spent thereon. Just as we travel too cheaply on the tubes and omnibuses of the metropolis, so we buy our cement too cheaply, and what is more, unnecessarily cheaply, for if we come to think of it, one shilling more per ton on Portland cement makes all the difference to the cement maker, but means quite an infinitesimal increase, say, on a £25,000 building. This craze for cheapness was not only detrimental to the prosperity of the country, but it brought with it certain dangers—namely, the danger of the smaller cement maker, who had perhaps to skimp and scamp some portion of his work in order to bring the cost of his product down to the low selling-price favoured.

To repeat—as an architect—he thought that the members of the technical professions looked upon cutting of prices with a certain amount of fear; it made their responsibility as regards inspection and supervision much greater and their duties far more arduous, and it did not always necessarily mean that the building owner got the same product that he expected to get when his professional adviser specified that the quality should be of the best. As in Portland cement, so it was in many other matters the modern tendency for cheapness and cutting was not only detrimental to the industry, but detrimental to the nation's standing and the prosperity of the individual.

Mr. C. H. Colson, M.Inst.C.E., proposed a vote of thanks to the hosts. He said he believed the works they had seen was one of the largest in the world, and certainly the most interesting in England. Mr. J. Munro seconded the motion, which were suitably supported and acknowledged.

CATALOGUES, ETC.

First Cottbus Cement Goods and Machine Works, whose London offices are at 1 Laleham Road, Catford, S.E., have sent us a quarto catalogue illustrative of the various machines supplied by them, hollow block, solid block, tile-making, etc., and it will be seen from their catalogue that this firm seems to be eminently equipped with different types of machinery and tools applicable to all cement users. Tools for surface treatment, colour spraying, etc., are also catalogued by this firm, together with their special process for cement pipe making, porous drain-pipe making, and the necessary wooden moulds for fence posts, kerbs, etc. The catalogue speaks volumes for the extraordinary number of uses to which cement is being applied for practical purposes. There seems no reason why its application should not be equally popular

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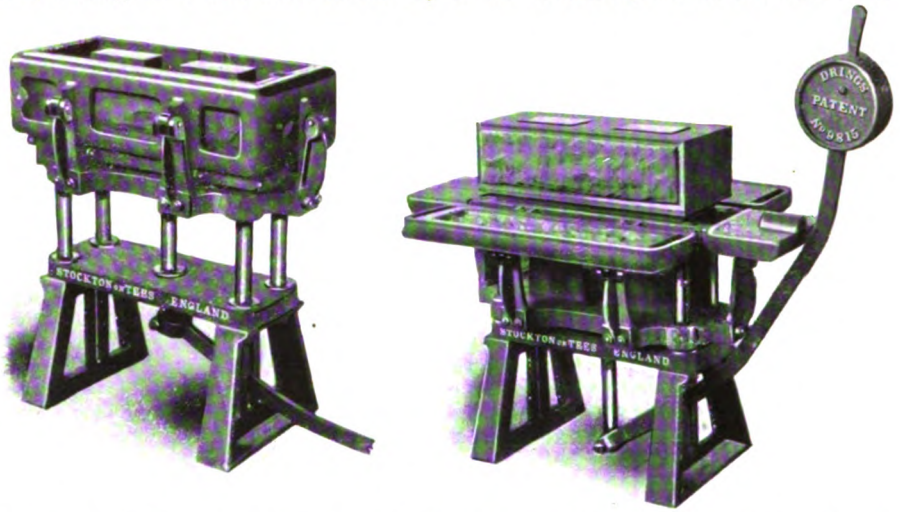
in many districts in this country. Probably the most remarkable feature indicated in the catalogue is the use of large concrete blocks for public places and ecclesiastical buildings.

The Stockton Stone and Concrete Co., Ltd., of Norton, near Stockton-on-Tees, have just put on the market Dring's Patent Building Block Machines for the manufacture of any kind of hollow or solid building blocks up to 2 ft. 8 in. in length by 9 in. thick and 10 in. high.

The appliance comprises a substantially built mould box, the sides and ends of which are hinged to a fixed table, and which when closed are held in position by wedge-shaped standards carried by a plate capable of being vertically actuated by a weighted lever working on a fulcrum. On lowering the plate by the upward movement of the lever the standards instantly release the sides and ends of the mould, which, resting on rollers fitted in the top of the standards, are at a uniform rate



lowered to a horizontal position, leaving the block on the pallet plate clear and ready for removal.

The cores used for the manufacture of hollow building blocks are adjustably fixed to the movable plate, and are withdrawn by the same movement of the lever. All intricate mechanism appears to be entirely eliminated, and the machine is worked simply by one action. By lowering the lever the machine is closed and locked, the cores placed in position, and again by raising the lever the mould is automatically opened, the cores withdrawn, and the block left clear for easy removal.

EDITORIAL MEMOS.

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PUBLISHER'S NOTICES.

DATES OF ISSUE.—This Journal is issued Monthly. For Advertisement Rates apply to Publisher. Matter for displayed advertisements required by 12th of month prior to subsequent issue, for Wants column by 18th.

SUBSCRIPTION RATES (Prepaid.—Post free)

Great Britain, the Colonies, and all Foreign countries. **12/6 per annum.**

The **Triennial** Subscription is **35/-** (three years).

Address remittances to Concrete Publications, Ltd.

General Offices:
Dewar House, Haymarket, London, S.W.

Telegraphic Address: "Concretius London."
Telephone No.: 6577 Gerrard

AGENTS.—For Australia: Messrs. Gordon and Gotch. For South Africa: The Central News Agency, Ltd. For Canada: The Toronto News Company and the Montreal News Company.

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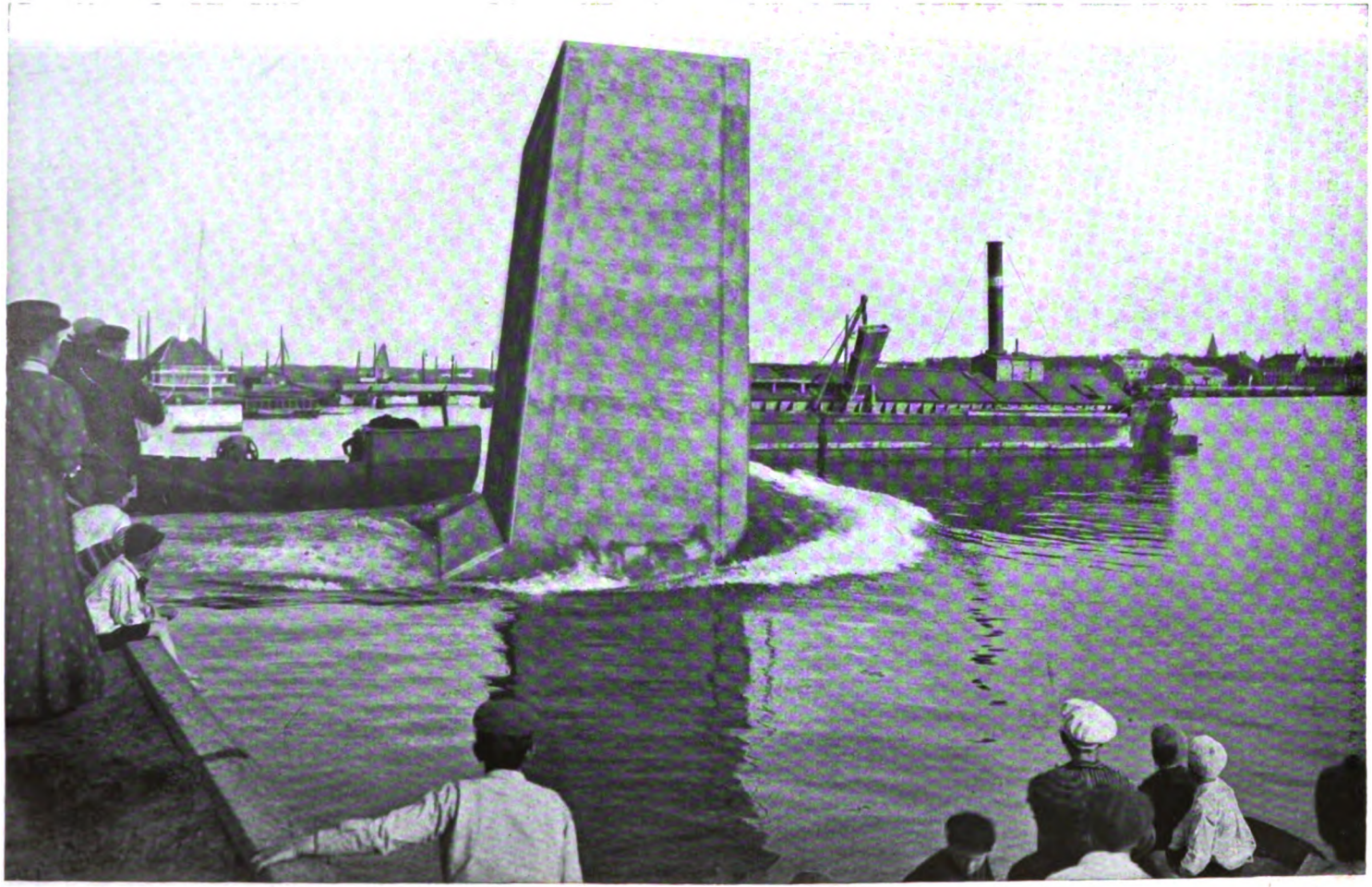

REINFORCED CONCRETE CAISSON BEING LAUNCHED AT NORRESUNDBY, DENMARK.
(*See Article on Reinforced Concrete and Portland Cement in Denmark, page 299.*)

Frontispiece.
(*Opp. Contents.*)

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume IV. No. 5. LONDON, OCTOBER, 1909.

EDITORIAL NOTES.

OUR MONTHLY ISSUE.

IN our previous issue we announced that this journal, which had been published as a bi-monthly for more than three years, had commenced to appear as a monthly.

We now desire, in a few words, to tender our thanks to the many readers who have so courteously written to us to express their appreciation of this development in our publication.

The advance in the use of concrete and reinforced concrete in recent years is very remarkable, and it may be expected that, with the rapidly growing interest in these materials among building owners, their technical advisers and contractors, the development of concrete and reinforced concrete will be even more rapid in the future.

Whatever we are able to do to assist in spreading useful information as to concrete, reinforced concrete, and their constituents will be done, and we shall continue to present particulars of new works in concrete and reinforced concrete that are of technical interest, whilst also giving publicity to new uses to which these materials can be applied.

THE INTERNATIONAL CONGRESS ON TESTING MATERIALS.

THE International Congress on Testing Materials, which was held at Copenhagen last month under the management of the International Association for Testing Materials, was an exceptionally successful gathering of those scientifically and industrially concerned in Iron, Steel, Concrete, Reinforced Concrete, Portland Cement, and various other materials.

The Congress was the fifth of a series, and whilst formerly practically the whole of the time of the conference used to be devoted to questions of iron and steel, the working hours were on this occasion almost equally divided between iron and steel on the one side, and concrete, reinforced concrete, and Portland cement on the other, showing the extraordinary increase of interest now taken in the last-named subjects. As a matter of fact, the work of the Congress had to be divided into three sections, the two primary ones (A and B) being devoted respectively to the questions named above, the third or minor section (C) giving a few hours to questions relating to certain other materials, such as indiarubber, timber, paint, etc.

In membership the International Association has become so large that while its increased strength and the increasing attendance at the triennial Congresses speak for the greater attention now given to matters of research generally, the

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actual working of the meetings has become somewhat unwieldy. In fact it may some day become necessary to divide the work of the Association between two distinct Congresses to be held alternately for the discussion of the respective subjects of sections A and B named above. For 750 members of the Association, as on this occasion, to be present at a general Congress and also at the social gatherings has considerable disadvantages; speaking and hearing become a strain at the former, and the possibility of acquaintances meeting is made more difficult at the latter. If in future the Congress is not divided, it will be necessary to limit the attendance to 500, by reducing the number of delegates allowable from any one public authority or society, and restricting what might be termed the "hangers-on" of a Congress of this kind who only join the Association for a short period in order to participate in a specific Congress without, however, taking part in the routine work of the Association.

THE CONGRESS GENERALLY.

The Congress as indicated was held at Copenhagen. It enjoyed the presence and patronage of the King of Denmark, whilst the Crown Prince of Denmark acted as Honorary President, reading the opening address. The President was Mr. Alex. Foss, a well-known Danish authority on matters relating to Portland cement and concrete, the secretarial work on the science side was in the hands of Mr. Reitler, of Vienna, and the local management in the hands of Captain Petersen, of Copenhagen. The sectional organisation comprised a number of honorary presidents, and among these were Mr. J. E. Stead, F.R.S., on the iron and steel section, Mr. Edwin O. Sachs, F.R.S.Ed., on the concrete and cement section, and Mr. J. T. Milton (of Lloyd's Register) on the miscellaneous materials section. The Secretary of the Iron and Steel Institute, Mr. G. C. Lloyd, represents Great Britain on the Council of the Association.

THE PAPERS AND DISCUSSIONS.

The only British paper presented was that by Mr. J. E. Stead, F.R.S., on "Macroscopy and Microscopy in the Workshop and Foundry" at a general meeting, and the only report of importance presented by a British representative was that of Mr. Bertram Blount, F.I.C., published in this issue; but, generally speaking, the Congress was all too prolific in reports, papers, appendices to papers, notes and special contributions of literary matter, very little of which it was possible to seriously discuss at so large a gathering.

Nevertheless, in the concrete, reinforced concrete, and cement section, to which this journal gave special attention, a three days' meeting (each meeting of four hours' duration) accomplished a considerable amount of useful work. This was chiefly due to the excellent management of the local chairman, Captain Grut, of the Danish Royal Engineers, who arranged for those presenting papers (which had been previously printed) to give them in a summarised form of a few minutes' duration only, and very strictly limited the scope and extent of each individual participating in the discussion.

THE SOCIAL ASPECT AND THE LANGUAGE DIFFICULTY.

Regarding the social aspect of the Congress, as the majority of those who count in questions of research in structural materials were present, it may be realised that the meeting was very useful for the informal discussion of many

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points on which there are divergent opinions. The renewal of old and the forming of new acquaintances were facilitated, regardless of the crowded attendance at the Congress, by a number of banquets, conversazioni, and excursions, notable among the latter being an excursion to the peninsula of Jutland.

The language difficulty was not so marked as on previous occasions, a very large number of the members having apparently gradually made up their minds to become conversant with at least one additional language to their own, and there was a marked effort made to present good summarised translations of the contributions to the discussions. All papers, too, had been summarised in at least two languages besides the one in which they were written. Thus almost every paper could be perused in English, German, and French.

REPORTS OF PROCEEDINGS.

A weak spot from the English point of view was the fact that there was no form of prompt reporting and printing of the discussions as presented from day to day. It should have been quite possible to have reported, transcribed, and printed the discussions every night after each day's work, this being simply a matter of administration, facilitated by the fact that the meetings always terminated at 2 p.m., and that a record was taken by phonograph.

Taken, however, generally, the Congress was most successful, and, above all, it marked the increasing interest in research work throughout the world, and Great Britain in particular showed a far greater interest than usual, a point which was favourably commented upon in the presidential address.

THE WORK OF THE CONCRETE, REINFORCED CONCRETE, AND PORTLAND CEMENT SECTION OF THE INTERNATIONAL CONGRESS.

It would be impossible to attempt to summarise the work of the concrete, reinforced concrete, and Portland cement section, and we now merely give a list of the papers put forward for discussion, and in a later issue we shall indicate some few of the resolutions arrived at by the Congress.

The papers presented read as follows :—

PAPERS, ETC., ON REINFORCED CONCRETE.

Report of the International Commission on Reinforced Concrete. Presented by the Chairman. Prof. F. Schüle, Zurich, with the following appendices :—

(a) *Wissenschaftliche Versuche und Versuche zur Kontrolle der Bauausführung auf dem Gebiete des Eisenbetonbaues in Deutschland.* Mitgeteilt vom Deutschen Ausschuss für Eisenbeton, Berlin.

(b) *Expériences et essais de contrôle sur le béton armé en Italie.* Rapport de M. le prof. J. Benetti, Bologne.

(c) *Eisenbetonversuche in Dänemark.* Mitgeteilt von Prof. E. Suenson, Kopenhagen.

(d) *Versuche mit Eisenbeton-Konstruktionen in Holland.* Mitgeteilt von S. J. Rutgers, Rotterdam.

(e) *Recherches expérimentales sur le béton armé en Suisse.* Rapport de M. le Prof. F. Schüle, Zurich.

Reinforced Concrete Structures. Measure of the Deformations of Structures under Service Conditions. By Charles Rabut, Paris.

The Prevention of Failures in Reinforced Concrete Structures. By Dr. Fr. v. Emperger, Vienna.

Influence of Repeated Loading upon the Adhesion between Concrete and Iron on Bright and on Rusty Surfaces. By Prof. Bernhard Kirsch, Vienna.

The Influence of Small Sectioned Transverse Ties on the Strength of Concrete. System of Free Ties. By W. P. Nekrassow, St. Petersburg.

PAPERS, ETC., ON METHODS OF TESTING AND TESTS.

Progress in the Methods of Testing Hydraulic Cements. Official report presented by R. Feret, Boulogne-sur-mer.

Uniform Tests of Hydraulic Cements by Means of Prisms. Standard Sand. Report of the Chairman of the Committee, Prof. F. Schüle, Zürich.

On Accelerated Tests of the Constancy of Volume of Cements. Report presented by the Chairman of the Committee, Bertram Blount, F.I.C., London.

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Rapid Methods for Determining the Strength of Hydraulic Cements. The Committee's Report presented by Dr. Fr. Berger, Vienna.

Note on the Rapid Testing of Cements treated with Hot Water. By L. Deval, Paris.

Note on Rapid Methods for Determining the Strength of Hydraulic Cements. By Alfred Greil, Vienna.

Determination of the Simplest Method for the Separation of the Finest Particles in Portland Cement by Liquid and Air Processes. Report of the Committee presented by Prof. M. Gary, Gr.-Lichterfelde.

Unification of Specifications for Gypsum. By Prof. M. Gary, Gr.-Lichterfelde, and R. Feret, Boulogne-sur-mer.

Testing Puzzolanas with the Object of Determining their Value for Mortars. By G. Herfeldt, Andernach.

On the Best Manner of Determining the Commencement and the Time of Setting. Hardness Test, by H. Laborbe, Us. St. Germains, near Beffes, France.

The Setting of Roman and Portland Cement as Paste, in Mortars and Concrete. By order of the Hungarian Society for Testing Materials, presented by Prof. Dr. Const. Zielinski, Budapest.

The Bonding of Layers of Mortar after Different Time Intervals. By Prof. B. Kirsch, Vienna.

On the New German Standards for the Uniform Delivery and Testing of Portland Cement. By M. Gary, Gr.-Lichterfelde.

PAPERS, ETC., ON CEMENT IN SEA WATER.

Experiments on the Decomposition of Mortars by Sulphate Waters. By J. Bied, Le Teil (Viviers).

On the Condition of the Cement Blocks in Some of the Russian Ports in the Black and Caspian Seas. By W. Czarnomski, St. Petersburg.

The Use of Reinforced Concrete Beside the Sea. By Prof. M. Möller, Brunswick.

Cement in Sea Water. By A. Poulsen, Copenhagen.

THE CONCRETE INSTITUTE.

PART III. of the first volume of the *Transactions of the Concrete Institute* is before us, and it completes the first year's record of the Institute's work.

The *Transactions* contain no less than 160 pages devoted to papers presented, with records of the discussions that have taken place, whilst there are also some 40 pages of preliminary matter dealing with the internal work of the Institute.

The publication is a remarkable indication of the useful work it has already been possible to do in the first year of the Institute's existence, and we also think it indicates the interest which the members are giving to its work.

As to the strength of the Institute, we observe that it now exceeds 800, and having regard to the fact that a large number of these 800 members are professional men of eminence, we certainly think that in strength and influence the Institute is second to none of the older associations which were formed abroad to deal with concrete and kindred subjects.

If the Institute was not first in the field as far as the world's concrete associations are concerned, it bids fair to take the first place in prestige, in the same manner as the Iron and Steel Institute stands first for those connected with the iron and steel industry.

THE PORTLAND CEMENT INDUSTRY.

WHILST the Portland cement industry of Great Britain has been unsatisfactory owing to the depression in the building and allied trades, it is pleasant to observe that the Associated Portland Cement Manufacturers (1900), Ltd., have been able to hold their own during the financial year ending June 30th, 1909, their position being much the same as in the previous year. That their position has been so maintained appears to be primarily due to economies effected in production and administration, to thoroughness in management, and also perhaps to a certain extent to the fact that this company is not solely dependent on Portland cement, but also manufactures other products not generally associated with its name, such as, for instance, plaster, "Keene's cement," and the like.

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THE PORTLAND CEMENT INDUSTRY.

The annual meeting of the Associated Portland Cement Manufacturers (1900), Ltd., is generally the occasion for the presentation of an interesting summary of the position, not only of the Portland cement industry, but of the concrete and reinforced concrete trades. This year Mr. F. A. White, the chairman, as on previous occasions, made a most interesting speech, which not only covered the subject in a most instructive manner, but also showed an outlook of somewhat brighter character than it has been previously possible to present.

We have on earlier occasions published quotations of Mr. White's address, and this time we will similarly give some paragraphs from his speech.

Speaking on reinforced concrete the following were his words :—

CONCRETE AND REINFORCED CONCRETE.

"Reinforced concrete construction holds the field at home and abroad. Apart from its greater use in this country, both by Government Departments and by private individuals and corporations, there has been considerable progress made in facilitating its use in districts where it had been difficult to employ it economically, owing to local regulations. Thus, for instance, the London Building Act Amendments contained in the London General Powers Bill have now received the Royal assent, and it will be possible for the London County Council to make regulations for the use of reinforced concrete in the Metropolis, which should materially lighten certain existing restrictions. Several provincial centres, such as Mancheser, have likewise been accorded the necessary powers by Parliament. These London Building Act Amendments facilitate the employment of steel-frame structures in the Metropolis. This will materially increase the use of Portland cement concrete, for not only will the larger proportions of floors used in steel-frame structures be of that material, but as the whole of the steel-framing has to be protected by some fire-resisting material, and as the fire-resisting material most favoured by experience and experiment is concrete, the effect upon the consumption of cement must be considerable. Another development is indicated by the fact that two or three of the English railway companies have given orders for reinforced concrete sleepers to take the place of wooden ones. This opens a large prospect, as does also the fact that already more than one factory is being erected on the banks of the Thames for the manufacture of concrete telegraph poles, tramway standards, and fence posts. As characteristic of the advance of the interest of the technical professions in reinforced concrete I should mention that the Institution of Civil Engineers, which held aloof from taking any active part in enquiring into this material, have now recently appointed an influential committee to make certain enquiries and to undertake certain research work in connection with reinforced concrete, and it is to be hoped not only that its work will be useful, but that means will be found for co-ordinating its researches with others that have already been undertaken in this country and in other parts of Europe. What an important *rôle* this question is playing in the world may be gathered from the fact that the International Testing Association, which held its meeting at Copenhagen this month, had present no less than 750 delegates representing innumerable municipal authorities and institutions, and that of the three sections into which the Association's work was divided one was entirely devoted to concrete, reinforced concrete, and Portland cement, and that the delegates included not only those from Europe and the United States, but many representatives from the Colonies and from distant countries, such as Japan, China, and the South American States."

PORTLAND CEMENT MANUFACTURERS AND THEIR CLIENTS.

Regarding a recent visit of the Concrete Institute to the works of this company, it is interesting to observe that Mr. White referred to this in his address, and explained how and why visits of this description are welcomed by the firm,

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and why they open their doors in a far wider sense than is the case in many other industries. The reference is as follows :—

"Your directors embrace all suitable opportunities of establishing or improving relations with those whose position makes it important for them to know the care that is given by the company to sustain the quality of its manufacture. In this connection a visit paid to our Swanscombe (J. B. White & Bros.) works in July last, on our invitation, by the members of the Concrete Institute, an organisation formed to bring together all interested in concrete construction, gave us great satisfaction. This institution, which was founded last year under the presidency of the Earl of Plymouth, formerly First Commissioner of Works, has developed with unprecedented rapidity, and what was a small body when we met last year now has a membership of over 800. It has been doing much to investigate the technical advantages and limitations of concrete and reinforced concrete. We attached considerable importance to this visit, for the membership of the institution includes many, if not most, of the leading authorities in this country upon the use of Portland cement and concrete. Further, a number of British cement manufacturers are also members, and we were particularly pleased to include these gentlemen in our invitation and to give them the opportunity of seeing for the first time the results of our expenditure and labour in creating at Swanscombe the largest and most modern works for the manufacture of Portland cement, not only in this country, but, we believe, in the whole of Europe. I do not think I need hesitate to say that the magnificent installation of rotary kilns and plant and the whole general appearance of the works made a considerable and favourable impression upon our visitors on that occasion, as, indeed, they had previously done upon others when the works were in a more incomplete state. With Swanscombe I may couple the works of our Knight Bevan and Sturge branch, where we have a similar, though not quite so large, installation of rotary kilns."

ACTIVITY IN THE COLONIES AND ABROAD.

We note with satisfaction that the company are paying attention to the Colonies and to distant countries, for work of this kind upholds British prestige and commerce generally. The following gives us some idea of their organisation in this direction :—

"Amongst other steps that we have taken, we instituted a system of travelling representatives whose business it should be, not so much to obtain orders themselves as to assist, both on the technical and on the commercial side, the agents we already had in foreign countries. In most—in fact, I think I may say, in all —of these countries which have to import cement we have agents for our various brands who themselves have usually been established in their respective localities for long periods, and who possess their own organisations and means of distribution. It is the aim of the emissaries I have spoken of to inspect and keep these agencies thoroughly alive. They are equipped with the knowledge to enable them to render service of particular value on technical questions. This we find is much appreciated, not only by the agents, but, what is more important still, by their customers, who are only too thankful to receive assistance and up-to-date information in dealing with the many problems presented by the new uses to which Portland cement is now being applied. The scope of these representatives extends to South Africa, India, and the East generally—Egypt, Argentina, Chili, Brazil, Mexico, and wherever necessity calls them. The cost must obviously be considerable, but your directors are satisfied that such an outlay is not only beneficial, but has become absolutely necessary in the company's interest."

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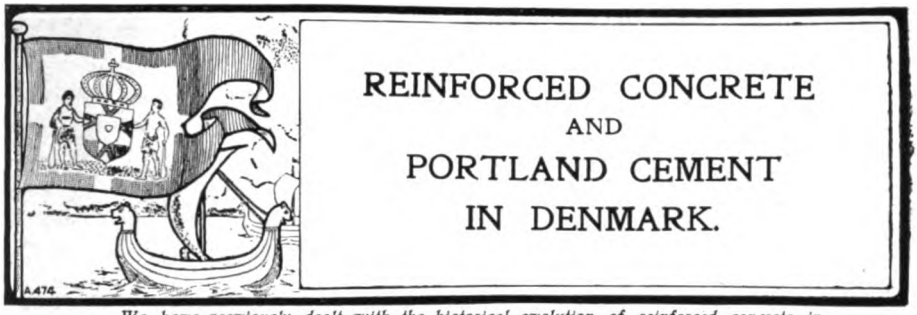

We have previously dealt with the historical evolution of reinforced concrete in Denmark, the article being one of a series describing this evolution in various countries.

In the current article will be found illustrations showing the application of reinforced concrete in Denmark, and particulars as to the development of concrete, reinforced concrete, and Portland cement in that country.—ED.

THE meeting of the International Commission on Reinforced Concrete at Copenhagen afforded its members an excellent opportunity of gauging the progress made in Denmark in the production of Portland cement and the application of that useful material to works in concrete and reinforced concrete.

On an earlier occasion—in our issue of November, 1908—we gave some particulars of the development of reinforced concrete in Denmark, and presented various illustrations. We now propose to amplify the article published on that occasion, which was in the main of an historical character, by showing a number of illustrations of important works in reinforced concrete and by giving some additional particulars as to what is being done with concrete, reinforced concrete, and Portland cement in that country.

CONCRETE IN DENMARK.

As far as concrete, as such, is concerned, one might summarise the position by saying that wherever it is possible to apply mass concrete it is being applied in Denmark, particularly in its splendid coast defence. Concrete is also being used to a considerable extent for what might be termed the minor equipment of buildings and structural works. It is largely used for pipes, hollow blocks, tiles, and the like. There is nothing very novel in the application of concrete for these purposes in Denmark, inasmuch as German models are generally followed. In pipe work alone the efficiency of the work calls for favourable comment. The presence, however, of concrete in every direction impresses the visitor and shows him the extraordinary number of purposes to which it can be economically applied. So far as coast protection work in particular is concerned, professional men concerned in this department of civil engineering would do well to visit Jutland, the west coast of which abounds with interesting examples deserving their attention.

REINFORCED CONCRETE IN DENMARK.

In respect to reinforced concrete, we have mentioned in the article referred to the advent of this material as dating from 1891, and during the last 10 years its increased use has been quite extraordinary. It is applied in every direction for many purposes and by all manner of building owners.

Works in course of progress visited by the members of the Commission included reinforced concrete foundations and floors for the Christianborg Palace at Copenhagen, where some £25,000 is being spent in reinforced concrete, tunnelling, viaducts, and foundations for the new Government railway station at Copen-

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hagen (where a similar amount is being expended in reinforced concrete). Quite a number of minor works were also visited.

Turning to recent examples of reinforced concrete work we are indebted to Captain Grut, of the Danish Royal Engineers, for some of the illustrations which we are enabled to present of work conducted under his supervision. It may be remembered that of such work that has come under his direction the reinforced concrete viaduct for the municipal gasworks at Copenhagen has been

Reinforced Concrete Bridge at Langaa.

Reinforced Concrete Bridge over Railway at Vejle.
REINFORCED CONCRETE BRIDGES IN DENMARK.

referred to in a previous issue of "Concrete"—*i.e.*, on pp. 360–361 of the preceding volume. This viaduct remains one of the most interesting examples of reinforced concrete to be found in Denmark. It was designed on the Hennebique system, and we add some further illustrations in this article.

We are also showing illustrations of an important bridge at Tietgen taken during the course of construction and upon completion (*see* p. 302). We would

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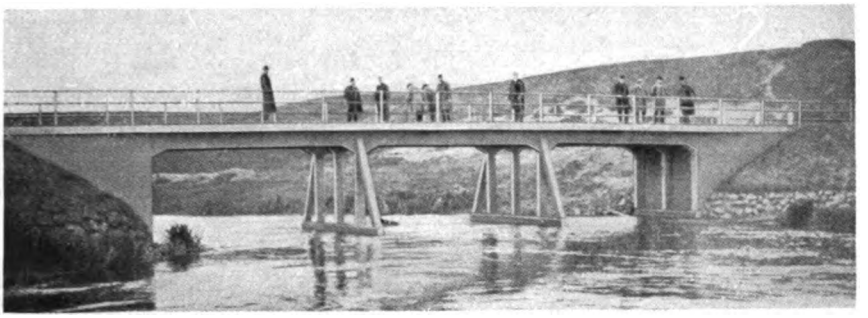
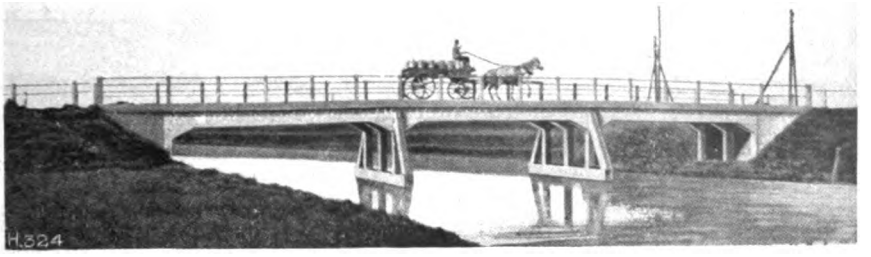
mention that the Hennebique system is favoured by this engineer, who, like several other Danish Royal Engineer officers, is allowed to act as a consultant for private work as far as his military duties permit.

We are indebted to Messrs. Christiani & Nielsen, of Copenhagen, for a most interesting series of illustrations of works executed by them in the capacity of specialist designers and contractors in reinforced concrete. Their work is not, as a rule, carried out on any one particular system, but is designed to accord with the latest ideas of structural practice.

In the first place we illustrate several of their bridges which are characteristic of the application of reinforced concrete generally to bridge work in Denmark. There is the Langaa Bridge (*see* p. 300), having a length of 38.5m., a width of

Reinforced Concrete Bridge at Bramminge.





Reinforced Concrete Bridge at Aabybro.
REINFORCED CONCRETE BRIDGES IN DENMARK.

4.5m. There is another bridge at Bramminge (on this page) with a length of 20.5m. and a width of 5.2m., with reinforced concrete pile foundations, and there is another, the Aaby Bridge at Aabybro, the first of its kind, built entirely of reinforced concrete, with a length also of 26m. and a width of 5m. There is also the railway bridge at Vejle (*see* p. 300) with a length of 39.5m. and a width of 9m., erected on concrete piles of 10m. depth.

Lastly, there is the excellent Southern bridge over the Gudina, near the Randers, with a length of 77m., a width of 13m., and reinforced concrete piles 14.5m. long for the foundations (*see* p. 303).

Before leaving the question of bridges we would call attention to a bridge recently completed in the Danish possession of Iceland which is remarkable

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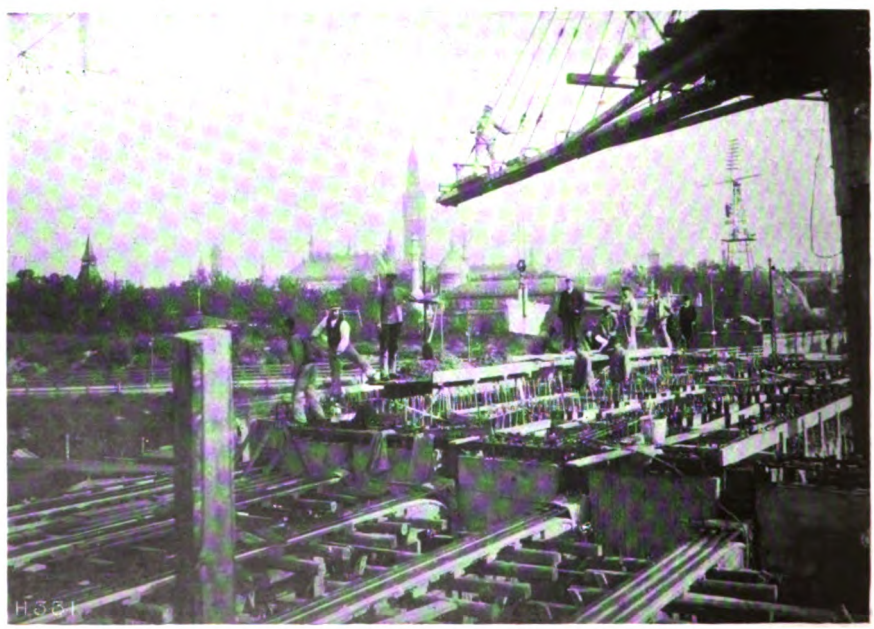
for the excellence of its design. It is the bridge at Frojska, near Skogar, which has a span of 54m. and a width of 2.5m. (*see* pp. 304 and 305). This example is so interesting that we are presenting some illustrations of it in course of construction, and it certainly reflects great credit upon Messrs. Christiani & Nielsen.

View of completed structure



View in course of erection.
REINFORCED CONCRETE BRIDGE AT TIETGEN.

Mentioning works of exceptional interest by the same firm, we now turn to the wharves which are in course of construction at Norresundby Harbour, and which have been executed with the aid of reinforced concrete caissons, which were launched and floated into position. This work, which was executed under the

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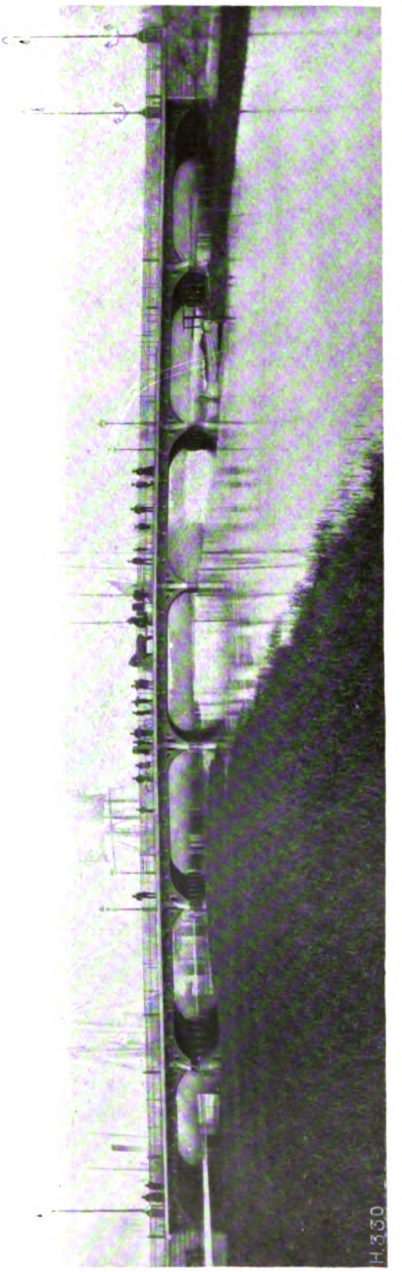
supervision of Mr. N. C. Monberg, is a very interesting example of how exceptional difficulties can be overcome, economically, with the aid of reinforced concrete. The caissons in question, of which we show a number of illustrations, and also illustrate as a frontispiece one in the moment of being launched, are 8m. high, 2.7m. wide, and 10m. long. Tugs towed them into position, and they were then sunk at the required points.

This wharfage work brings one to notice the fact that a favourite application of reinforced concrete in Denmark is small piers for harbours, bathing places, and the like, and one of these, also designed by Messrs. Christiani & Nielsen, at Hundested, is illustrated. A smaller one, executed by the Danish Concrete Beam Co., at Wedellsborg, is also presented. This company, by-the-by, more closely fulfils the description of its work—namely, in the construction of hollow beams for pontoons and the construction of telegraph posts. We illustrate a reinforced concrete pontoon, 22m. long, as used by the Danish Navy Department at the suggestion of Captain Moehl, of the Danish Royal Engineers, and we also show in this issue various types of telegraph poles and electric transmission poles which are now being erected in Denmark to Captain Moehl's specification (*see* "New Uses").

Altogether, the examples presented afford most striking evidence of the increasing interest in reinforced concrete in Denmark, and, read together with our preceding articles, indicate the extraordinary advantages which the new material possesses for a country where economy is the essence of administration.



REINFORCED CONCRETE BRIDGE AT RANDERS

The amount of reinforced concrete to be found in Denmark, with its comparatively small area and population, is indeed interesting and remarkable.

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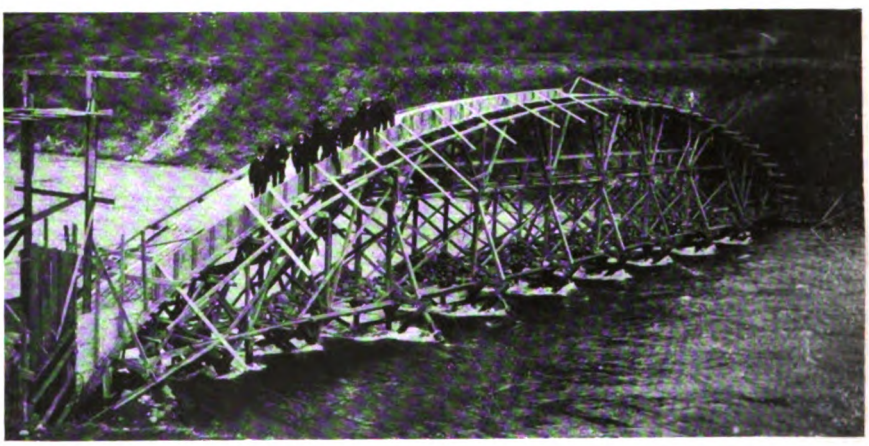

REINFORCED CONCRETE BRIDGE AT SKOGAR (ICELAND)
(Views taken in course of construction.)

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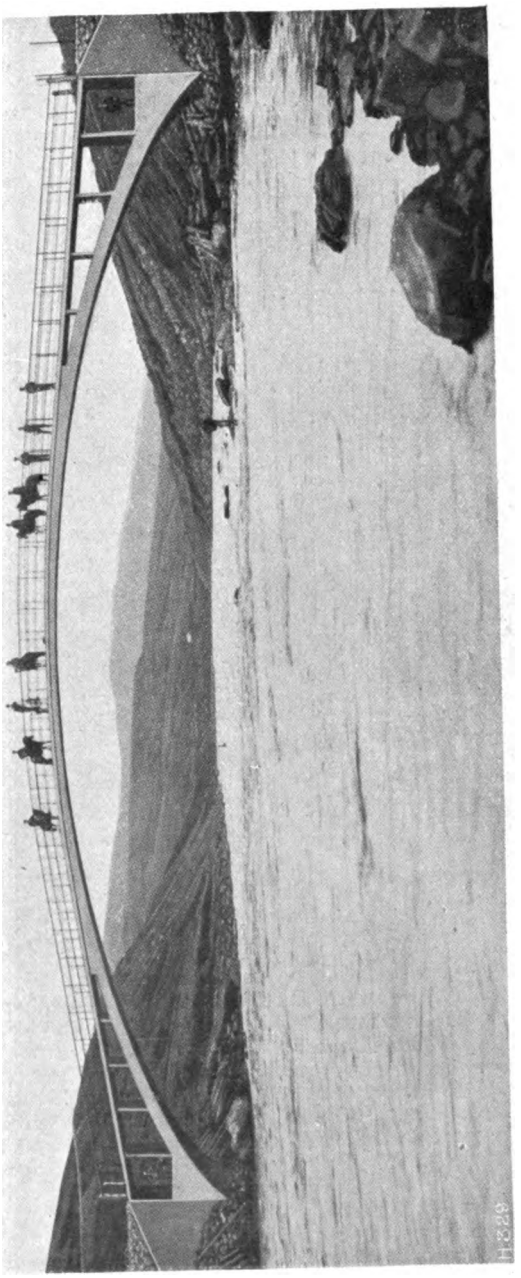
Regarding the Portland cement industry of Denmark, the development of which has so obviously favourably influenced the use of concrete and reinforced



REINFORCED CONCRETE BRIDGE AT SKOGAR (ICELAND.)

concrete in Denmark, we think we cannot do better than summarise the position as put forward by Mr. Paul Larsen, of Messrs. F. L. Smidth & Co., of

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Copenhagen, in an exhaustive paper read at the opening meeting of the International Congress on Testing Materials. The following is the summary :—

THE DEVELOPMENT OF THE DANISH CEMENT INDUSTRY.

Mr. Paul Larsen said it was on the existence of the chalk in a condition suitable for technical purposes that the Portland cement industry of Denmark was based. This industry, which had now reached a high degree of perfection, had been mainly built up during the last 20 years, often under most difficult conditions, and without any support whatever from the State.

The following figures illustrated the development of the Danish Portland cement industry during the past 20 years :—In the year 1889 the total production in Denmark was 115,000 barrels Portland cement, the importation being 135,000 barrels; in the year 1908 the total production was 1,560,000 barrels, of which 1,110,000 barrels were sold in Denmark and 410,000 barrels were exported, whereas the importation had decreased to less than 100,000 barrels. The present capacity of the Danish cement

REINFORCED CONCRETE PONTOON FOR THE NAVY.

factories was, however, 2,600,000 barrels, or more than twice the consumption of the country. A drawback for the success of the cement trade lay in the circumstances that the country was absolutely devoid of water-power and coal, the result being that fuel, which is so important a factor for this trade, must be imported from abroad; but here the cement manufacturer met with the extraordinary difficulty that the State imposed an import duty on coal and thus made this very important raw material still more expensive. Similar conditions formerly prevailed in respect to material for packing, such as staves for casks, iron hoops and bags, on which articles a proportionately high import duty was levied by the State, whereas on the other hand the foreign cement- inclusive of its packing—had always been imported free of duty into Denmark. It was not until the 1st of January of the present year that the effect of this absurdity was diminished by the passing of the new Danish tariff. On the other hand most of the countries to which Portland cement could be exported from Denmark on account of the natural geographical conditions had protected their industries by high tariffs. Only England, Germany, Belgium and Holland had no duty on cement.

In spite of these difficulties the Danish cement industry had now reached a

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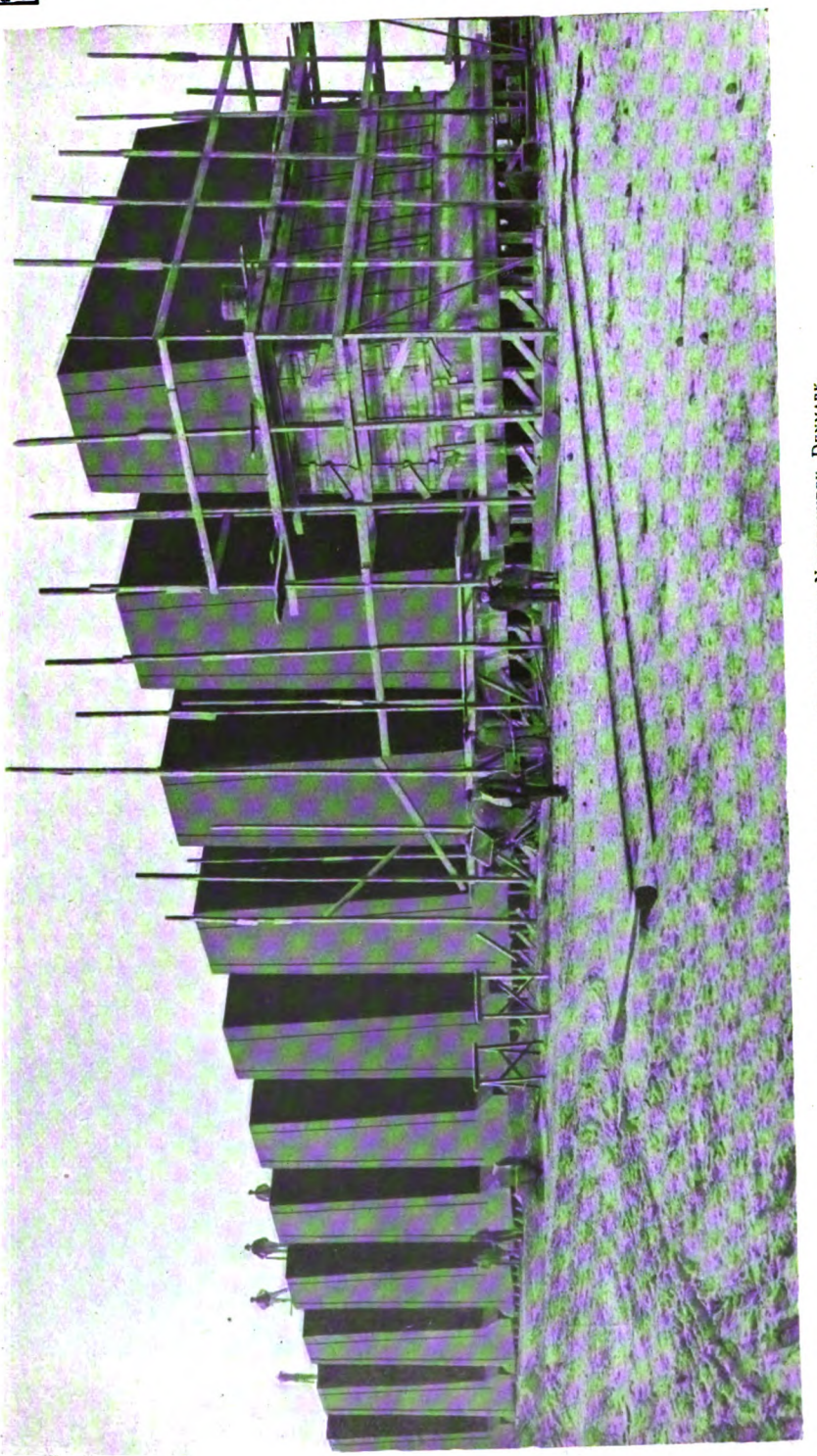

REINFORCED CONCRETE CAISSONS PRIOR TO LAUNCHING AT NORRESUNDBY, DENMARK.

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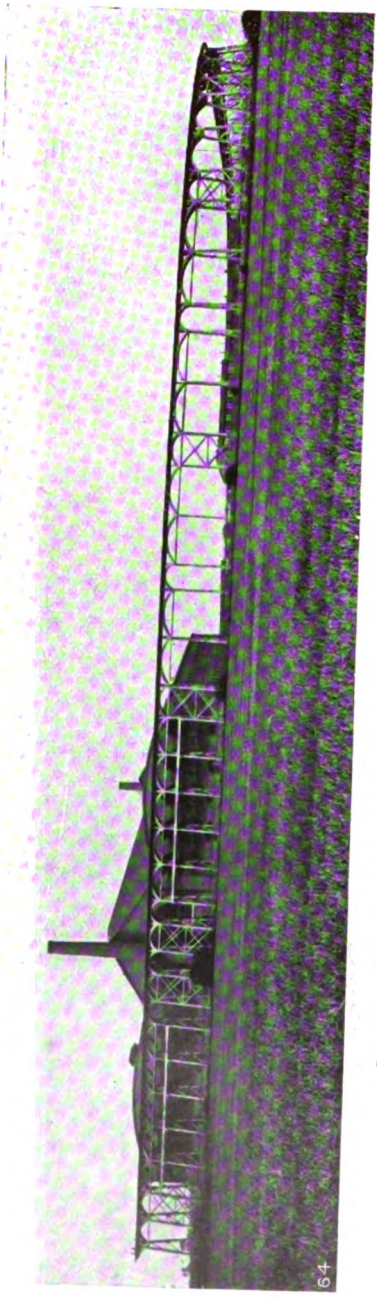

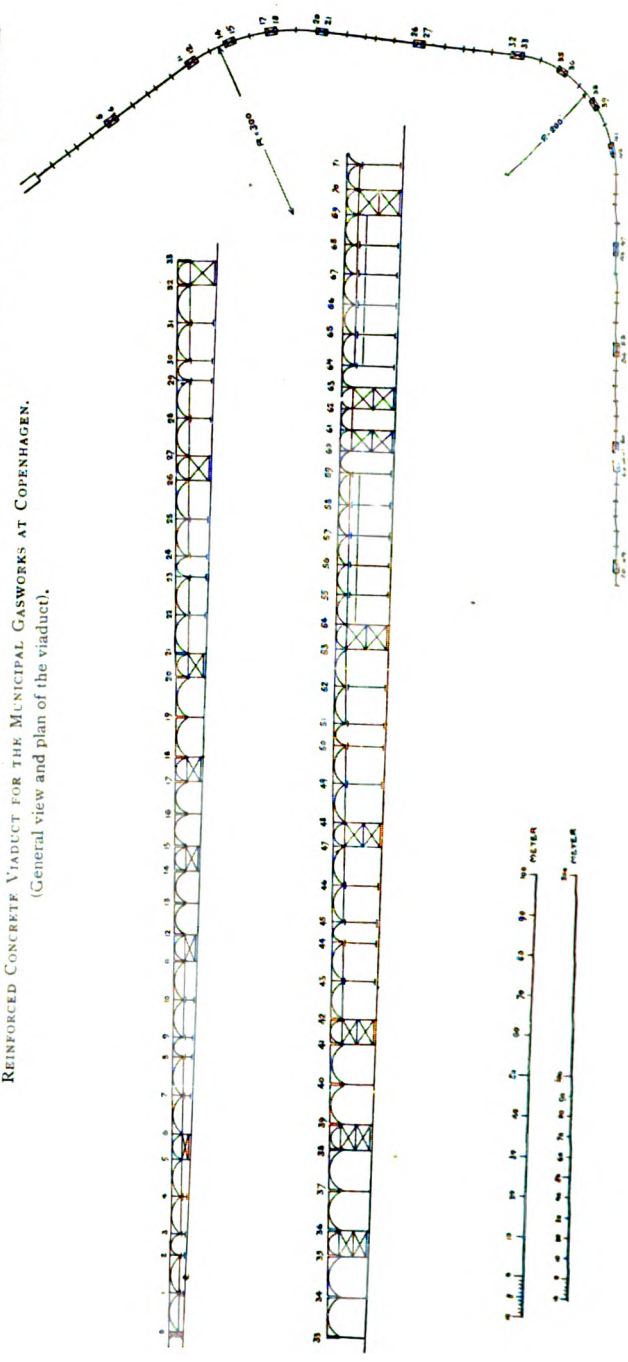

Reinforced Concrete Viaduct for the Municipal Gasworks at Copenhagen.
(General view and plan of the viaduct).

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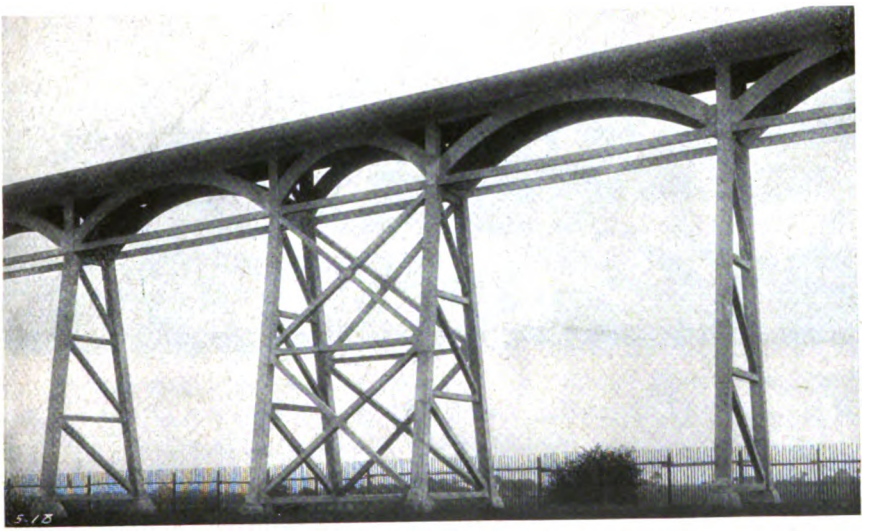

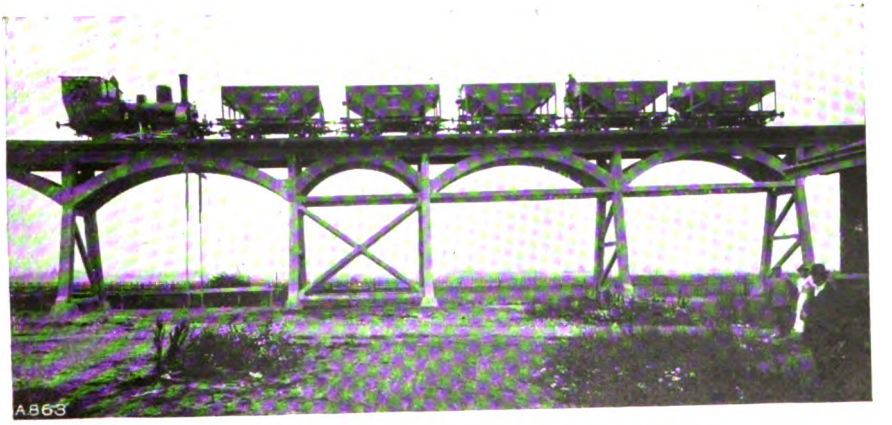

REINFORCED CONCRETE VIADUCT FOR THE MUNICIPAL GAS WORKS AT COPENHAGEN.
(Views of various bays.)

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standpoint from which it was able to cope with the industries of the surrounding countries. This was mainly due to the advanced state of its technical development.

A report on Danish cement manufacture would thus to a large extent be a report on Danish technical improvements, but the country and its trade was too small to show the value of these improvements with sufficient clearness. Only in demonstrating the influence which these improvements had had on the development of the industry in the larger countries was it possible to throw sufficient light on the question.

Reinforced Concrete Pier at Wedellsborg.

Reinforced Concrete Landing Stage at Hundested.
REINFORCED CONCRETE PIER

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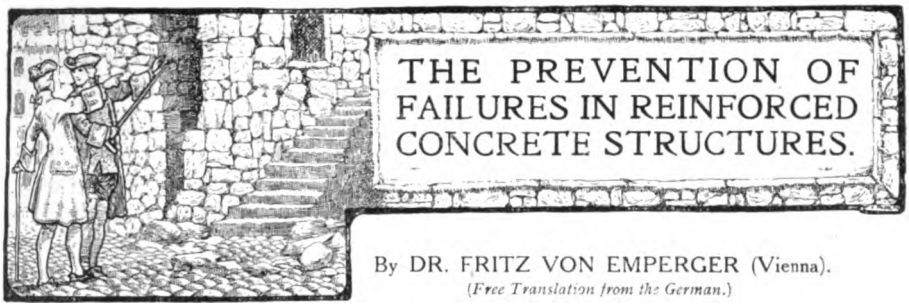

THE PREVENTION OF FAILURES IN REINFORCED CONCRETE STRUCTURES.

By DR. FRITZ VON EMPERGER (Vienna).

(Free Translation from the German.)

Among the many contributions on the occasion of the meeting of the International Commission on Reinforced Concrete at Copenhagen, the paper herewith presented as an appendix to the Commission's report calls for publication in full, and the eminent author's deductions claim careful attention. Dr. von Emperger, it may be remembered, is the Editor of our contemporary, "Beton und Eisen."

The primary deduction of the author is that the methods of obtaining reliable records as to failures should be improved, and the arrangements for making tests must be systematically developed if failures are to be avoided.

We concur with the author that the number of failures in reinforced concrete is decreasing rapidly if compared with the great amount of additional work executed.—ED.

In order to form a correct judgment on this question suitable statistics are wanting. It will not do to form our opinions from isolated serious accidents.

Individual great disasters of all kinds—as, for instance, those met with on the sea—sink into insignificance as far as their death roll is concerned in comparison with the accumulated totals of those everyday occurrences of which we think so little.

To give one example only, according to the lists of the Workmen's Union for Iron Bridge and Iron House Buildings in the State of Illinois, the number of deaths in 1905 were as many as 26, that of men incapacitated for work reaching the same figure, and that of the slightly injured amounting to 80, out of a membership of 1,350 workmen—that is to say, in all about 10 per cent. of the men met with some form of accident, grave or slight. This figure rose in 1906 to 156 cases, or 12 per cent., a circumstance which was attributed to excessive haste in the execution of the work.

In view of such figures we must allow that we have no idea of the amount of the blood tax which modern buildings demand throughout the civilised world, nor of the waste of national property represented by carelessly erected buildings that have fallen in. We must say to ourselves, then, that a proper scheme for the prevention of accidents must take statistics of casualties of this kind as its main basis, and that accidents, speaking generally, are, as a matter of fact, promoted in a high degree by the hushing-up methods hitherto employed in the building trade for the simple reason that neither science nor practice gets the chance of applying the lessons that are to be learnt from them.

As the first step in this direction attention may be called to the report of Rutger's "Bauunfälle in Holland," which was presented to the "International Commission on Reinforced Concrete," and contains material of great value.

In recognition of this circumstance, I have in my "Handbuch für Eisenbeton" given the question of accidents on buildings the large amount of space which it deserves, and in the following short description I must make reference to this treatise.

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The occurrences—generally known as accidents or failures—may be divided into two groups: *unpreventable ones*, in which forces come into play which are not amenable to calculation; and *preventable ones*, that is to say, such as, in view of the present state of our knowledge of the causes, could with due exercise of caution have been prevented.

Unfortunately an addition will have to be made to these two main groups of a third one, called for short the *negligence group*, which comprises those accidents in which ignorance or thoughtlessness, or even carelessness plays a part—unhappily an unavoidable evil, with which, in spite of all advances in science, we still have to reckon.

The last-named but most dangerous group of building casualties must lose in extent in the degree in which knowledge of the domain in question increases and extends, and legal and professional means are taken to safeguard this branch of work from ignorance and carelessness. The yearly number of such occurrences, if compared with the large increase of work done, will be found to be rapidly decreasing.

In illustration of a large number of occurrences of this kind, it will not be out of place to touch shortly upon the so-called concessionaire system. This is an arrangement which was created by M. Hennebique, on the basis of which a large plan manufactory arose in Paris—to which several branches were subsequently added—its object being to supply plans (at a percentage remuneration) to firms which had no drawing offices of their own. Now, while M. Hennebique exercised a considerable amount of care in the choice of his concessionaires, so that the natural consequences of this separation of design from execution did not under his direction come so clearly to the surface, many of his imitators have overstepped the bounds of all reason. In this manner contractors were set to carry out reinforced concrete structures, who were complete strangers to the class of work required of them. This has been carried to the greatest lengths by certain American companies who have made it their business to sell special reinforcing bars or rods for reinforced concrete. In order to carry out their object, which solely consisted in the selling of large quantities of specially rolled sections, the commercial office was supplemented by a designing office, the advice of which, however, could but rarely stand in the way of the main object in view—namely, the sale of sections. Orders were obtained promiscuously for buildings on the basis of the specialist firm's plans which specified the use of the special bars by practically anyone who presented himself. As far as the original "metal merchant" was concerned, the business was concluded with the supply of the specified quantity of bars.

It is notable that the greatest number of accidents occurred during a period of inflation, in which firms that treated the reinforced concrete only as an article of commercial speculation had ample opportunities of doing business, regardless of the question whether their technical officials were able to meet the requirements made on them or not.

In view of such phenomena, conscientious reinforced concrete contractors are in a difficult position. They should never accept more work than they are

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able to execute with the staff of experienced men at their disposal. A special branch of this kind demands special knowledge, and a firm that employs experienced specialists should necessarily command higher and more regular prices; and such a firm alone should be in a position to avoid the occurrence of sad experiences such as those above referred to. In connection with this expression of views a paper read by Geheimrat Launer (Berlin) before the VIIIth International Congress of Architects in Vienna, 1908, should be studied.

A. FAILURES FROM UNAVOIDABLE CAUSES.

In this connection the following causes come in question :—

1. *Earthquake.*—As is shown at San Francisco and Messina, the material which is the best able to withstand these forces has been found in reinforced concrete. Of course this assumes its application in a suitable form, and reference may in this respect be made to the proposals of the author for "earthquake-proof" structures. *(See our issue of September, 1909.)*

2. *Inundations, Lightning and Tempest, Fire.*—Here also reinforced concrete, if properly and suitably designed and carefully executed, may be regarded as the most practical and economic material with which as far as possible to resist these forces of nature.

3. *Exceptional Shock and Explosions.*—On this point it would be well to state that scientifically the power of resistance of reinforced concrete to exceptional shock has not yet been demonstrated, but we know from certain accidents in which great forces have been developed that such power of resistance must be great and that the coherence of the whole structure makes itself favourably conspicuous under such unfavourable circumstances.

B. FAILURES FROM PREVENTABLE CAUSES.

Noteworthy in connection with the following is the circumstance that no collapse of a completed building that has been handed over for service is known to have occurred anywhere, and that it has always, therefore, been a question of mistakes which proper construction would have been able to prevent, while minor deficiencies in quality were made good from time to time.

1. *Errors in Shuttering.*—The engineer must know how strong he has to make the mould so that it will not break. Building casualties of this kind result either from too weak a shuttering, from an over-burdening of the shuttering in the concreting, or from its too early removal.

An example of weakness of the centering is supplied by the collapse of the Bridgemann Building in Philadelphia on July 9, 1907, and of the store in 1906 at Bern. Mention may here be made of two of the greatest catastrophes which have been due to this cause of weakness, viz., the collapse of the Bixby Hotel at Longbeach in California, and that of the mill at Marquette, near Lille. In connection with this type of failure we may also refer to the accidents which have occurred on the application of the test loads immediately after the removal of the shuttering. There are, for instance, the collapses of the buildings in Milan on April 17, 1908, and in Corning in 1904.

It may here be observed that the supervision of a reinforced concrete building in most localities seems to extend to everything except to the quality and kind of the centering.

It is nothing out of the common, then, when it is further reported, in connection with the case of the above-mentioned Bixby Hotel in California, that for the building of the attic storey, which was not included in the original design, and which is stated to have been the immediate cause of the collapse, the contractor had collected all the old broken timber that was to be found on the job to make the centering.

It would accordingly be desirable to publish a number of standard drawings of

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centerings, such as might supply pattern and scale to the contractor and to the supervising engineer as to what should be required.

2. *Mistakes in the Construction of the Pillars.*—Mistakes of this kind in the construction of the vaulting reach back into the history of the time before the advent of reinforced concrete. In the case of beams a defective design may produce a small shift, which interferes with the intended continuity. Numerous examples might be cited.

A properly made pillar that is well connected with the beam gives the latter a kind of firm support which is much greater and much surer than that attained by the continuity. Unfortunately current practice and our rules hitherto only take account of the latter. Special experiments with girders firmly fixed at their ends and of frame-like arrangement would be necessary in order to clear up this hitherto dark domain so far that we may understand how to avail ourselves of those advantages and to proportion the girders to the capabilities shown by them without waste of iron.

An improperly arranged pillar may be a source of danger. The best known example of this is the collapse of the Hotel " zum goldenen Bären " in Bâle in 1903.

3. *Mistakes in Calculation.*—In the first place we may refer to a mistake which, well known as it is in steel frame construction, has not been sufficiently attended to in the domain of reinforced concrete. This is the circumstance that, quite apart from the degree of strain permissible, a certain limit of deflection should not be exceeded.

Among the permissible stresses the adhesive strength, as the foundation of the structural connection, is the one that is most often sinned against. Here experiment, by means of which the quality of an arrangement can be demonstrated, comes to its rights and often shows to what false conclusions the so-called practical sense may in such cases lead. The question as to the proper arrangement of the reinforcements in order to obtain the best connection, by means of which alone it is possible to obtain the full value of the metal, or at least to reach the degree of adhesion usually considered attainable, has been on a good many false scents, which have often caused considerable injury to the buildings concerned. As examples of the collapse of buildings which were designed without stirrups may be mentioned that of the railway bridge at Luino over the canal near Bataglia. These phenomena appear—as indeed is everywhere the case—with particular prominence when several faults occur at the same point. Thus, for instance, if a defective stirrup arrangement is combined with concrete of inferior (clayey) aggregates, or concrete that has been badly mixed and perhaps has air bubbles between stirrups and insertion rods or expansion pieces, the destruction of the girder is a necessary consequence.

The tensile strength of steel is to-day the safest basis for our calculations. A questionable matter and one to be decided by experiment might be the influence of the tensile strength of the concrete and its shearing strength in the case of ribbed beams. In the absence of exact knowledge of these properties the tendency is only too great, from pure motives of caution, to set up working requirements which go far beyond anything that is necessary, and in contradistinction to the necessary and dangerous properties here referred to, may be designated as national waste. This is particularly the case in regard to the compressive strength of the iron under compression in the upper chord of the girder. In regard to the former, I have repeatedly shown that the reference of the compressive strength of actual practice to that shown in the testing of sample cubes is only possible when the former is almost doubled. The useless arrangement of compression rods has been inveighed against by Prof. Schüle.

In all these cases the testing system shows itself as the only guide for a proper solution of the problems involved, and it should be employed to a greater extent.

4. *Mistakes in the Production of Concrete.*—Occurrences in this domain in the first place comprise those in which the use of bad mixing-water, bad aggregates or bad

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cement is involved. While it was formerly looked on as sufficient to have a representative test of the cement made, it is now recognised that this is insufficient in all cases in which special requirements of a high order are made on this material: that what to our practical judgment ought to give a good concrete may be far removed from being a suitable material for reinforced concrete, and that in this connection also the testing system has the last word to say. While the readiness to contribute towards the cost of tests displayed by several of the State departments, and specially by the Deutscher Betonverein, may be gratefully recognised, it must not be forgotten that contractors in general are not yet convinced of their necessity.

Of the influences which can destroy concrete, mention may first be made of faulty production, such for instance as the pouring in of the concrete during heat or frost, or an insufficient adhesion between the successive layers of this material. Finally, there comes in question the subsequent destruction of the concrete by sea-water, aciduous springs, subsoil water, and such like, as also by means of oil, petroleum, and other fluids. In this domain also the test system is in progress to enlighten us as to the magnitude of the dangers and the means of avoiding them.

5. *Destruction of the Iron.*—Only the destruction of the iron by rust comes in question here. The cases in which the formation of rust has been increased by the covering of the iron with poor concrete are rare, since a good concrete covering is easy to make. Fraught with danger are the electrical phenomena resulting from potential differences or stray currents, and finally many of the innocent-looking additions made to concrete, such as that of common salt during the occurrence of frost. A salty concrete afterwards becomes hygroscopic and promotes the formation of rust.

CONCLUSION.

In view of these manifold circumstances, which may give rise to accidents in building, doubts were entertained in many quarters, on the introduction of reinforced concrete, whether it would be possible to find contractors of so trustworthy a nature and with their workmen so well organised that they could steer clear of all rocks. The best proof that this is so is the immense amount of work which has already been thoroughly and successfully accomplished.

It must further be pointed out that every locality which is in possession of a good code of regulations with reference to such work, has been exempt from considerable disasters of this kind, and this to such a degree that the assertion is justified that the methods of prevention of accident by properly conceived regulations hitherto adopted are the right ones.

The present treatment of the statistics regarding failures and of the question of the publication of these occurrences must be described as faulty, and the endeavours to develop both the methods of obtaining reliable records of actual failures and to improve the testing system in all the branches here referred to, deserve the greatest encouragement.

It is only in this way—by means of a better recognition of the circumstances under which failures occur and by systematic testing—that we can put ourselves in a position to prevent failures in future and to avoid the methods of construction which may be bad.

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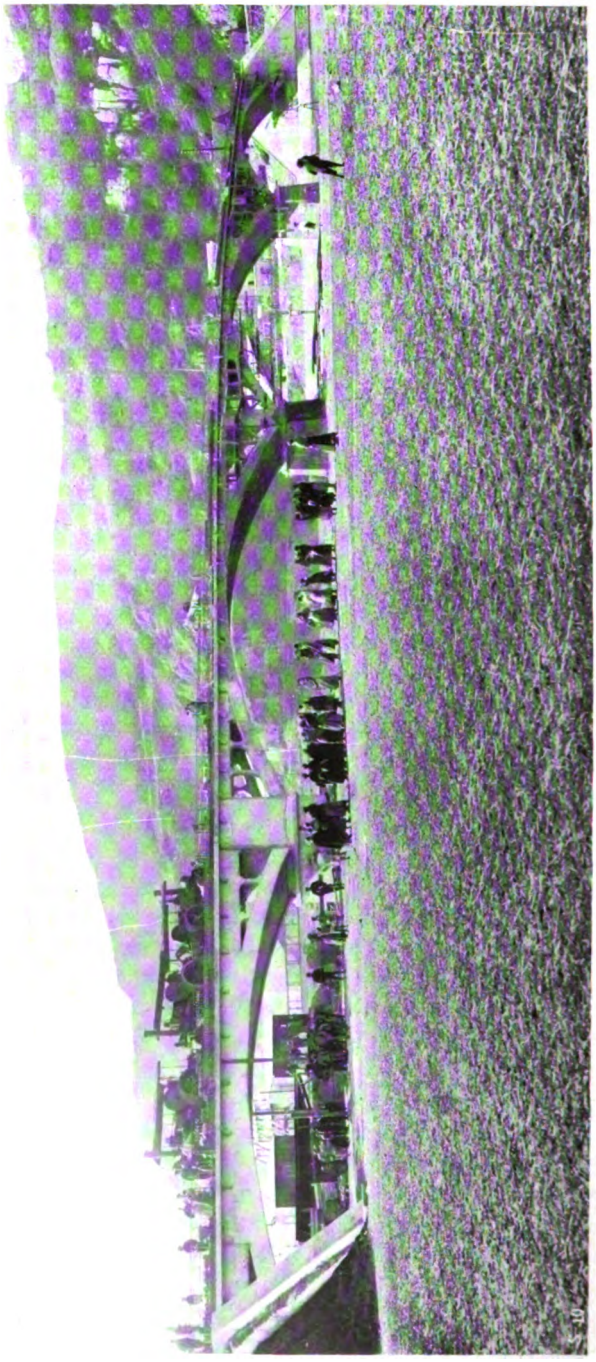

HERMALLE BRIDGE, NEAR HUY (BELGIUM).
(Length of bridge, 175 metres. Span of central arch, 48 metres.)

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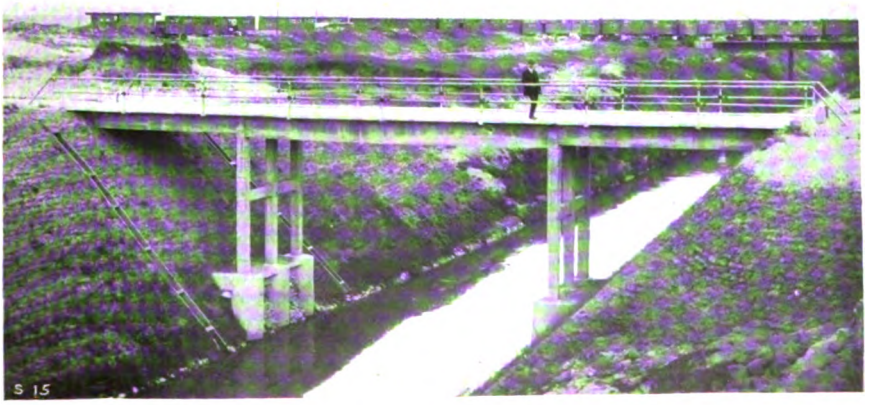
REINFORCED CONCRETE BRIDGES.

We have from time to time published particulars of reinforced concrete bridges constructed in different parts of the world, and we are continuing to present illustrations in this issue, principally with a view of indicating the increasing popularity of the use of reinforced concrete for bridge work.—ED.

THE illustrations presented in this article refer exclusively to bridges erected on the Hennebique system, and we are indebted to the head office of Messrs Hennebique, at Paris, for the photographs from which our reproductions have been prepared.

It is not our intention to give particulars in this article as to design, for our chief object in presenting these illustrations is to indicate some of the many types of bridges in existence which have been constructed in reinforced concrete, and thus to present additional evidence in favour of the use of this material, where economy both in first cost and maintenance is desired.

The advocates of reinforced concrete are still frequently met by scepticism at home and in the colonies, and it is only by ocular demonstration of the existance of bridges in reinforced concrete for all manner of purposes that we believe this scepticism will be gradually overcome.



BRIDGE OVER THE GRAND CANAL, NEAR MEXICO CITY.

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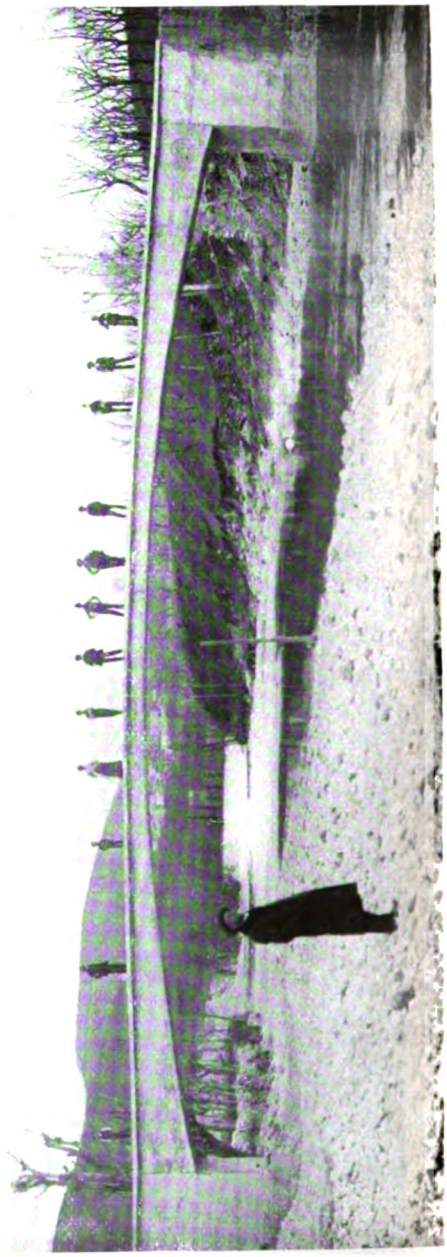
In another article in this issue we have also presented illustrations of a number of reinforced concrete bridges erected in Denmark, where no particular system appears to be specially favoured or subject to patent rights, and these two series

RAEVELS BRIDGE, OVER CAMPINE CANAL (BELGIUM).
(Central Span, 29 metres.)



BRIDGE OVER THE RIVER ADIGE, NEAR CALVENE (ITALY).
(34·5 metres span.)

of illustrations should afford some useful food for thought for those who have been lately opposing the application of reinforced concrete in bridge work.

We would add that we have particularly selected bridges for illustration in

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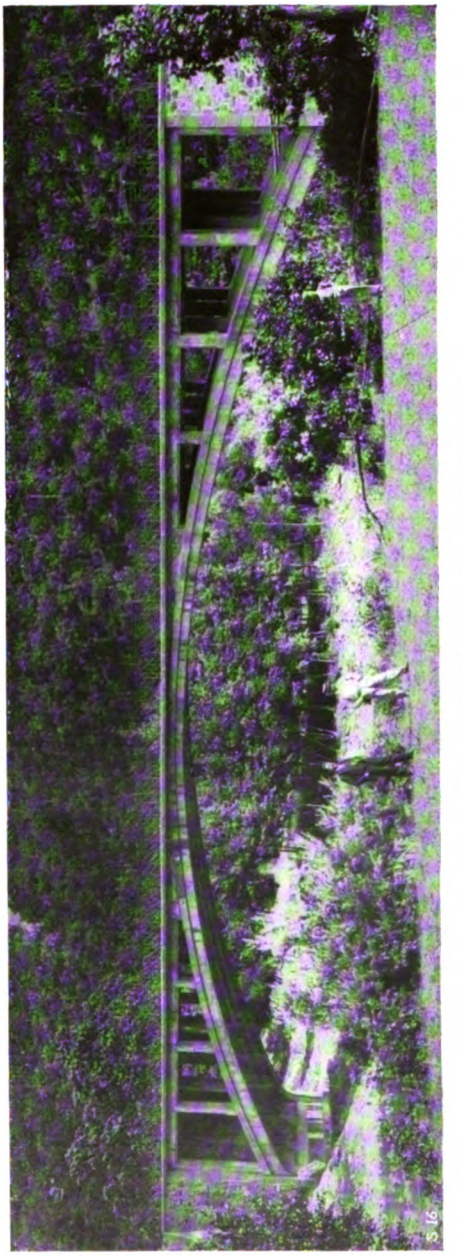
this issue, having regard to the Waterford controversy which was dealt with recently in our editorial columns, and we trust these illustrations will be found of interest to our readers.

FOOTBRIDGE OVER THE CHARENTE AT ANGOULEME (FRANCE).
(125 metres length. Central span, 23·6 metres.)



BRIDGE OVER THE RIVER BORMIDA, NEAR ISOLETTA (ITALY).
(50 metres span.

As to the various systems of design applied to bridge work, we think we cannot do better than refer to previous articles published in our journal.

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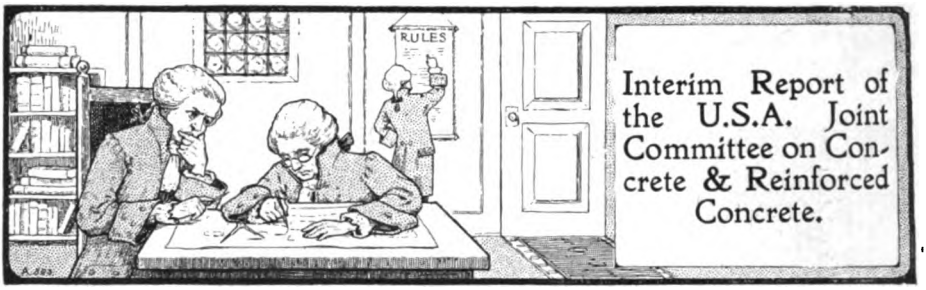

We are presenting herewith an important American Interim Report on Concrete and Reinforced Concrete which has now become public property and which certainly merits the closest attention of all those interested in Concrete and Reinforced Concrete. This interim report was approved at the end of last year, not only by the Joint Committee, but also by the affiliated committees of the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, and Association of American Portland Cement Manufacturers. All of these bodies carry weight, as indicating recent American views on this subject.

The draft, as a matter of fact, was approved by letter ballot in December, 1908, and the various societies named approved this interim report on varying dates between February and July of the current year.

We think special mention should be made of the fact that Mr. Richard L. Humphrey acted as Hon. Secretary to the Joint Committee, and that the excellence of reports is due very much to his industry, care, and tact.

We not only give the actual report, but present some details as to how it was arrived at, as this is a matter of some importance in considering its utility.—ED.

SPECIAL committees were appointed by the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, and the Association of American Portland Cement Manufacturers for the purpose of investigating current practice and providing definite information concerning the properties of concrete and reinforced concrete, and to recommend necessary factors and formulas required in the design of structures in which this material is used.

At the annual convention of the American Society of Civil Engineers held at Asheville, N.C., June 11th, 1903, the following resolution was adopted :—

"It is the sense of this meeting that a special committee be appointed to take up the question of concrete and steel concrete, and that such committee co-operate with the American Society for Testing Materials and the American Railway Engineering and Maintenance of Way Association."

Following the adoption of this resolution, a special committee on concrete and steel concrete was appointed by the Board of Directors on May 31st, 1904. At the annual meeting, held January 18th, 1905, the title of this special committee was, at the request of the committee, changed to "Special Committee on Concrete and Reinforced Concrete."

At the annual meeting of the American Society for Testing Materials, held July 1st, 1903, at the Delaware Water Gap, the following resolution was unanimously adopted :—

"That the Executive Committee be requested to consider the desirability of appointing a committee on 'Reinforced Concrete,' with a view of co-operating with the committees of other societies in the study of the subject."

At the meeting of the Executive Committee of this Society, held December 5th, 1903, a special committee on "Reinforced Concrete" was appointed.

The American Railway Engineering and Maintenance of Way Association

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appointed a Committee on Masonry on July 20th, 1899, with instructions as a part of its duties to prepare specifications for concrete masonry. A preliminary set of specifications for Portland cement concrete was reported to and adopted by the Association on March 19th, 1903. At the meeting held in Chicago on March 17th, 1904, the Committee on Masonry was authorised to co-operate with the special committee on Concrete and Reinforced Concrete of the American Society of Civil Engineers, and a special sub-committee was appointed.

At a meeting of the several special committees representing the above-mentioned societies, held at Atlantic City, N.J., June 17th, 1904, arrangements were completed for collaborating the work of these several committees through the formation of the Joint Committee on Concrete and Reinforced Concrete. Mr. C. C. Schneider was elected temporary chairman and Professor A. N. Talbot was elected temporary hon. secretary. Sub-committees were appointed on Scope, on Tests, and on Ways and Means.

Mr. Schneider and Mr. Schaub, as chairman and secretary of the special committee of the American Society of Civil Engineers, were elected permanent chairman and hon. secretary of the Joint Committee, and on the resignation of the latter Mr. Richard L. Humphrey was elected hon. secretary. The Joint Committee comprised 34 individuals, representing four corporate bodies of high standing. We understand there was a minority of three individuals who propose publishing a minority report.

The Interim Report now issued reads as follows:—

THE INTERIM REPORT.

ADAPTABILITY OF CONCRETE AND REINFORCED CONCRETE.

The adaptability of concrete and reinforced concrete for engineering structures, or parts thereof, is now so well established that it may be considered one of the recognised materials of construction. It has proved to be a satisfactory material, when properly used, for those purposes for which its qualities make it particularly suitable.

1. Proper Use.—Concrete is a material of very low tensile strength and capable of sustaining but very small tensile deformations without rupture; its value as a structural material depends chiefly upon its durability, its fire-resisting qualities, its strength in compression and its relatively low cost. Its strength increases generally with age.

Plain concrete or massive concrete is well adapted for structural forms in which the principal stresses are compressive. These include foundations, dams, retaining walls and other walls, piers, abutments, short columns and, in many cases, arches. In the design of massive concrete the tensile strength of the material must generally be neglected.

By the use of metal reinforcement to resist the principal tensile stresses concrete becomes available for general use in a great variety of structures and structural forms. This combination of concrete and metal is particularly advantageous in the beam, where both compression and tension exist; it is also advantageous in the column where the main stresses are compressive, but where cross-bending may exist. In structures resisting lateral forces it possesses advantages over plain concrete in that it may be so designed as to utilise more fully the strength rather than the weight of the material.

2. Improper Use.—Failures of reinforced concrete structures are usually due to any one or a combination of the following causes: defective design, poor material, and faulty execution.

The defects in a design may be many and various. The computations and assumptions on which they were based may be faulty and contrary to the established principles

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of statics and mechanics; the unit stresses used may be excessive, or the details of the design defective.

The design of reinforced concrete structures should receive at least the same careful consideration as those of steel, and only engineers with sufficient experience and good judgment should be entrusted with such work.

The computations should include all minor details, which are sometimes of the utmost importance. The design should clearly show the size and position of the reinforcement and should provide for proper connections between the component parts, so that they cannot be displaced. As the connections between reinforced concrete members are frequently a source of weakness, the design should include a detailed study of such connections, accompanied by computation to prove their strength.

The use of high unit stresses, approaching the danger line, is a defect in the design of reinforced concrete structures.

Articulated concrete structures, designed in imitation of steel trusses, may be mentioned as illustrating a questionable use of reinforced concrete.

Poor material is sometimes used for the concrete, as well as for the reinforcement. The use of inferior concrete is generally due to a lack of experience of the contractor and his superintendents, or to the absence of proper supervision.

An unsuitable quality of steel for reinforcement is sometimes prescribed in specifications, for the purpose of reducing the cost. For steel structures a high grade of material is specified, while the steel used for reinforcing concrete is sometimes made of unsuitable, brittle material.

Faulty execution and careless workmanship may generally be attributed to unintelligent or insufficient supervision.

While other engineering structures, upon the safety of which human lives depend, are generally designed by engineers employed by the owner, and the contracts let on the engineer's design and specification, in accordance with legitimate practice, reinforced concrete structures frequently are designed by contractors or by engineers commercially interested, and the contracts let for a lump sum.

The construction of buildings in large cities is regulated by ordinances or building laws, and the work is inspected by municipal authorities. For reinforced concrete work, however, the limited supervision which municipal inspectors are able to give is not sufficient. Means for more adequate supervision and inspection should, therefore, be provided.

3. Responsibility and Supervision.—The execution of the work should not be separated from the design, since intelligent supervision and successful execution can be expected only when both functions are combined. The engineer who prepares the design and specifications should, therefore, have the supervision of the execution of the work.

The committee recommends the following rules for structures of reinforced concrete, for the purpose of fixing the responsibility and providing for adequate supervision during construction:

a. Before work is commenced, complete plans shall be prepared, accompanied by specifications, static computations and descriptions showing the general arrangement and all details. The static computations shall give the loads assumed separately, such as dead and live loads, wind and impact, if any, and the resulting stresses.

b. The specifications shall state the qualities of the materials to be used for making the concrete, and the manner in which they are to be proportioned.

c. The strength which the concrete is expected to attain after a definite period shall be stated in the specifications.

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d. The drawings and specifications shall be signed by the engineer and the contractor.

e. The approval of plans and specifications by other authorities shall not relieve the engineer nor the contractor of responsibility.

f. Inspection during construction shall be made by competent inspectors employed by and under the supervision of the engineer and shall cover the following:

1. The materials.
2. The correct construction and erection of the forms and the supports.
3. The sizes, shapes and arrangement of the reinforcement.
4. The proportioning, mixing and placing of the concrete.
5. The strength of the concrete by tests of standard test pieces made on the work.
6. Whether the concrete is sufficiently hardened before the forms and supports are removed.
7. Prevention of injury to any part of the structure by and after the removal of the forms.
8. Comparison of dimensions of all parts of the finished structure with the plans.

g. Load tests on portions of the finished structure shall be made where there is reasonable suspicion that the work has not been properly performed, or that through influences of some kind the strength has been impaired. Loading shall be carried to such a point that twice the calculated working stresses in critical parts are reached, and such loads shall cause no permanent deformations. Load tests shall not be made until after 60 days of hardening.

4. Destructive Agencies: *a. Corrosion of Metal Reinforcement.*—Tests and experience have proved that steel embedded in good concrete will not corrode, no matter whether located above or below fresh or sea water level. If the concrete is porous so as to be readily permeable to water, as where the concrete is laid with a very dry consistency, the metal may be corroded in the presence of moisture.

b. Electrolysis. There is little accurate information available as to the effect of electrolysis on concrete. The few experiments that are available seem to indicate that concrete may be damaged through the leakage of small electrical currents through the mass, particularly where steel is embedded in the concrete. These experiments are not conclusive, however, and the large number of reinforced concrete structures subject to the action of electrolysis, in which the metal and concrete are in perfect condition, would seem to indicate that the destructive action reported was due to abnormal conditions which do not often occur in practice.

c. Sea Water.—The data available concerning the effect of sea water on concrete or reinforced concrete are inconclusive and limited in amount. There have been no authentic cases reported where the disintegration has proved to be due entirely to sea water. The decomposition that has been reported manifests itself in a number of ways; in some cases the mortar softens and crumbles, in others a crust forms which in time comes off. It has been found, however, that where concrete is proportioned in such a way as to secure a maximum density and is mixed thoroughly it makes an impervious concrete, upon which sea water has apparently little effect. Sea-walls have been standing for considerable lengths of time without apparent injury. In many of our harbours, where the water has been rendered brackish through the rivers discharging into them, the action that has been reported has been at the water line and was probably due in part to freezing.

d. Acids.—Concrete of first-class quality, thoroughly hardened, is affected appreciably only by strong acids which seriously injure other materials. A substance like

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manure, because of the acid in its composition, is injurious to green concrete, but after the concrete has thoroughly hardened it satisfactorily resists such action.

e. Oils.—When concrete is properly made and the surface carefully finished and hardened it resists the action of such oils as petroleum and ordinary engine oils. Certain oils, which contain fatty acids, appear to produce injurious effects.

f. Alkalies.—The action of alkalies on concrete is problematical. In the reclamation of arid land, where the soil is heavily charged with alkaline salts, it has been found that concrete, stone, brick, iron, and other materials are injured under certain conditions. It would seem that at the level of the ground water such structures are disintegrated, possibly due in part to the effect of formation of crystals resulting from the alternate wetting and drying of the surface of the concrete at this ground water line. Such destructive action can be prevented by the use of an insulating coating which will prevent this action from taking place.

MATERIALS.

A knowledge of the properties of the materials entering into concrete and reinforced concrete is the first essential. The importance of the quality of the materials used cannot be overestimated, and not only the cement, but also the aggregates, should be subject to such definite requirements and tests as will insure a concrete of the required quality.

I. Cement.—There are available for construction purposes Portland, natural and puzzolan or slag cements. Only Portland cement is suitable for reinforced concrete.

a. Portland Cement is the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials. It has a definite chemical composition varying within comparatively narrow limits.

Portland cement should be used in reinforced concrete construction and any construction that will be subject to shocks or vibrations or stresses other than direct compression.

b. Natural cement is the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas. While the limestone must have a certain composition, this composition may vary in much wider limits than in the case of Portland cement. Natural cement does not develop its strength as quickly, nor is it as uniform in composition, as Portland cement.

Natural cement may be used in massive masonry where weight rather than strength is the essential feature.

Where economy is the governing factor, a comparison may be made between the use of natural cement and a leaner mixture of Portland cement that will develop the same strength.

c. Puzzolan or slag cement is the finely pulverized product resulting from grinding a mechanical mixture of granulated basic blast furnace slag and hydrated lime.

Puzzolan cement is not nearly as strong, uniform or reliable as Portland or natural cement, is not extensively used and never in important work; it should be used only for foundation work underground where it is not exposed to air or running water.

d. Specifications.—The cement should meet the requirements of the Standard Specifications for Cement. A number of societies have been working on methods for testing and specifications for cement. The best practice seems to be represented in the standard methods of testing and specifications for cement which are the result of the joint labours of special committees of the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, American Institute of Architects, and others.

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2. ***Aggregates.***—Extreme care should be exercised in selecting the aggregates for mortar and concrete, and careful tests made of the materials, for the purpose of determining their qualities and the grading necessary to secure maximum density* or a minimum percentage of voids.

a. Fine aggregate consists of sand, crushed stone, or gravel screenings, passing when dry a screen having ¼-in. dia. holes. It should be preferably of silicious material, clean, coarse, free from vegetable loam or other deleterious matter.

A gradation of the grain from fine to coarse is generally advantageous.

Mortars composed of 1 part Portland cement and 3 parts fine aggregate by weight when made into briquettes should show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

b. Coarse aggregate consists of inert material, such as crushed stone, or gravel, which is retained on a screen having ¼-in. dia. holes. The particles should be clean, hard, durable, and free from all deleterious material. Aggregates containing soft, flat, or elongated particles should be excluded from important structures. A gradation of sizes of the particles is generally advantageous.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete from fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass, the size of the coarse aggregate may be such as to pass a 3-in. ring. For reinforced members a size to pass a 1-in. ring, or a smaller size may be used.

Cinder concrete is not suitable for reinforced concrete structures, and may be safely used only in mass for very light loads or for fireproofing.

Where cinder concrete is permissible the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburnt coal or ashes.

3. ***Water.***—The water used in mixing concrete should be free from oil, acid, strong alkalies, or vegetable matter.

4. ***Metal Reinforcement.***—The committee recommends as a suitable material for reinforcement steel filling the requirements of the specifications adopted by the American Railway Engineering and Maintenance of Way Association.

For the reinforcement of slabs, small beams, or minor details, or for the prevention of shrinkage cracks where wire or small rods are suitable, material conforming to the requirements of either specification A or B given in the Appendix may be used.

The reinforcement should be free from rust, scale, or coatings of any character which would tend to reduce or destroy the bond.

PREPARATION AND PLACING OF MORTAR AND CONCRETE.

1. ***Proportions.***—The materials to be used in concrete should be carefully selected, of uniform quality, and proportioned with a view to securing as nearly as possible a maximum density.

a. Unit of Measure.—The unit of measure should be the barrel, which should be taken as containing 3·8 cu. ft. Four bags, containing 94 lb. of cement each, should be considered the equivalent of one barrel. Fine and coarse aggregate should be measured separately as loosely thrown into the measuring receptacles.

b. Relation of Fine and Coarse Aggregate.—The fine and coarse aggregate should be used in such relative proportions as will insure maximum density. In unimportant work it is sufficient to do this by individual judgment, using correspondingly higher proportions of cement; for important work these proportions should be carefully deter-

* A convenient coefficient of density is the ratio of the sum of the volumes of materials contained in a unit volume to the total unit volume.

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mined by density experiments, and the sizing of the fine and coarse aggregates should be uniformly maintained or the proportions changed to meet the varying sizes.

c. Relation of Cement and Aggregates.—For reinforced concrete construction a density proportion based on 1 : 6 should generally be used—*i.e.*, 1 part cement to a total of 6 parts of fine and coarse aggregates measured separately.

In columns, richer mixtures are often required, while for massive masonry or rubble concrete a leaner mixture of 1 : 9, or even 1 : 12, may be used. These proportions should be determined by the strength or wearing qualities required in the construction at the critical period of its use. Experienced judgment, based on individual observation and tests of similar conditions in similar localities, is the best guide as to the proper proportions for any particular case.

2. Mixing. — The ingredients of concrete should be thoroughly mixed to the desired consistency, and the mixing should continue until the cement is uniformly distributed and the mass is uniform in colour and homogeneous, since maximum density and, therefore, greater strength of a given mixture depends largely on thorough and complete mixing.

a. Measuring Ingredients.—Methods of measurement of the proportions of the various ingredients, including the water, should be used, which will secure separate uniform measurements at all times.

b. Machine Mixing.—When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

c. Hand Mixing.—When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and colour.

d. Consistency.—The materials should be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, at the same time, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

e. Retempering.—Retempering mortar or concrete—*i.e.*, remixing with water after it has partially set—should not be permitted.

3. Placing of Concrete. — *a. Methods.*—Concrete, after the addition of water to the mix, should be handled rapidly, and in as small masses as is practicable, from the place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow-setting cement should be used when a long time is likely to occur between mixing and final placing.

The concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place of gravity and the surplus water has been forced to the surface.

In depositing the concrete under water special care should be exercised to prevent the cement from being floated away, and to prevent the formation of laitance, which hardens very slowly and forms a poor surface on which to deposit fresh concrete. Laitance is formed in both still and running water, and should be removed before placing fresh concrete.

Before placing the concrete care should be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from débris. When the placing of the concrete is suspended, all necessary grooves for joining future work should be made before the concrete has had time to set.

When work is resumed, concrete previously placed should be roughened, thoroughly

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cleansed from foreign material and laitance, drenched and slushed with a mortar consisting of 1 part Portland cement and not more than 2 parts fine aggregate.

The faces of concrete exposed to premature drying should be kept wet for a period of at least seven days.

b. Freezing Weather.—Concrete for reinforced structures should not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

c. Rubble Concrete.—Where the concrete is to be deposited in massive work its value may be improved and its cost materially reduced through the use of clean stones thoroughly embedded in the concrete as near together as is possible and still entirely surrounded by concrete.

FORMS.

Forms should be substantial and unyielding, so that the concrete shall conform to the designed dimensions and contours, and should be tight to prevent the leakage of mortar.

The time for removal of forms is one of the most important steps in the erection of a structure of concrete or reinforced concrete. Care should be taken to inspect the concrete and ascertain its hardness before removing the forms.

So many conditions affect the hardening of concrete that the proper time for the removal of the forms should be decided by some competent and responsible person, especially where the atmospheric conditions are unfavourable.

DETAILS OF CONSTRUCTION.

1. Joints. — *a. Reinforcement.*—Wherever in tension reinforcement it is necessary to splice the reinforcing bars the length of the lap shall be determined on the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at points of maximum stress should be avoided. In columns, large bars should be properly butted and spliced; small bars may be treated as indicated for tension reinforcement or their stress may be taken off by being embedded in large masses of concrete. At foundations, bearing plates should be provided for large bars or structural forms.

b. Concrete.—For concrete construction it is desirable to cast the entire structure at one operation, but as this is not always possible, especially in large structures, it is necessary to stop the work at some convenient point. This point should be selected so that the resulting joint may have the least possible effect on the strength of the structure. It is, therefore, recommended that the joint in columns be made flush with the lower side of the girders; that the points in girders be at a point midway between supports, but should a beam intersect a girder at this point, the joint should be offset a distance equal to twice the width of the beam; that the joints in the members of a floor system should, in general, be made at or near the centre of the span.

Joints in columns should be perpendicular to the axis of the column and in girders, beams and floor slabs perpendicular to the plane of their surfaces.

2. Shrinkage. – Girders should never be constructed over freshly formed columns without permitting a period of at least two hours to elapse, thus providing for settlement or shrinkage in the columns. Before resuming work, the top of the column should be thoroughly cleansed of foreign matter and laitance. If the concrete in the column has become hard the top should also be drenched and slushed with a mortar consisting of 1 part Portland cement and not more than 2 parts fine aggregate before placing additional concrete.

3. Temperature Changes. — Concrete is sensitive to temperature changes, and it is necessary to take this fact into account in designing and erecting concrete struc-

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tures. In some positions the concrete is subjected to a much greater fluctuation in temperature than in others, and in such cases joints are necessary. The frequency of these joints will depend, first, upon the range of temperature to which concrete will be subjected; second, upon the quantity and position of the reinforcement. These points should be determined and provided for in the design. In massive work, such as retaining walls, abutments, etc., built without reinforcement, joints should be provided, approximately, every 50 feet throughout the length of the structure. To provide against the structures being thrown out of line by unequal settlement, each section of the wall may be tongued and grooved into the adjoining section. To provide against unsightly cracks, due to unequal settlement, a joint should be made at all sharp angles.

4. ***"Fireproofing."***—The actual fire tests of concrete and reinforced concrete have been limited, but experience, together with the results of tests so far made, indicate that concrete may be safely used for " fireproofing " purposes. Concrete itself is incombustible and reasonably proof against fire when composed of a silicious sand and a hard, coarse aggregate such as igneous rock.

For a " fireproof " covering these same materials may be used or clean hard burned cinders may be substituted for the coarse aggregate.

The low rate of heat conductivity of concrete is one reason for its value for fireproofing. The dehydration of the water of crystallisation of concrete probably begins at about 500° F. and is completed at about 900° F., but experience indicates that the volatisation of the water absorbs heat from the surrounding mass, which, together with the resistance of the air cells, tends to increase the heat resistance of the concrete, so that the process of dehydration is very much retarded. The concrete that is actually affected by fire remains in position and affords protection to the concrete beneath it.

It is recommended that in monolithic concrete columns the concrete to a depth of 1½ in. be considered as protective covering and not included in the effective section.

The thickness of the protective coating required depends upon the probable duration of a fire which is likely to occur in the structure and should be based on the rate of heat conductivity. The question of the conductivity of concrete is one which requires further study and investigation before a definite rate for different classes of concrete can be fully established. However, for ordinary conditions it is recommended that the metal in girders and columns be protected by a minimum of 2 in. of concrete; that the metal in beams be protected by a minimum of 1½ in. of concrete, and that the metal in floor slabs be protected by a minimum of 1 in. of concrete.

It is recommended that the corners of columns, girders and beams be bevelled or rounded, as a sharp corner is more seriously affected by fire than a round one.

5. ***Waterproofing.***—Many expedients have been used to render concrete impervious to water under normal conditions, and also under pressure conditions that exist in reservoirs, dams and conduits of various kinds. Experience shows, however, that where mortar or concrete is proportioned to obtain the greatest practicable density and is mixed to a rather wet consistency, the resulting mortar or concrete is impervious under ordinary conditions. A concrete of dry consistency is more or less pervious to water, and compounds of various kinds have been mixed with the concrete, or applied as a wash to the surface for the purpose of making it watertight. Many of these compounds are of but temporary value, and in time lose their power of imparting impermeability to the concrete.

In the case of subways, long retaining walls and reservoirs, leakage cracks may be prevented by horizontal and vertical reinforcement, properly proportioned and located, provided the concrete itself is impervious.

Such reinforcement distributes the stretch due to contraction or settlement so that cracks are too minute to permit leakage, or are soon closed by infiltration of silt.

Ashphaltic or coal tar preparations, applied either as a mastic or as a coating on felt or cloth fabric, are used, and should be proof against injury by liquids or gases.

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6. *Surface Finish.*—Concrete is a material of an individual type and should not be used in imitation of other structural materials. One of the important problems connected with the use of concrete is the character of the finish of exposed surfaces. The finish of the surface should be determined before the concrete is placed, and the work conducted so as to make possible the finish desired. For many forms of construction the natural surface of the concrete is unobjectionable, but frequently the marks of the boards and the flat, dead surface are displeasing, making some special treatment desirable. A treatment of the surface, which removes the film of mortar and brings the coarser particles of the concrete into relief, is frequently used to remove the form markings, break the monotonous appearance of the surface, and make it more pleasing. Plastering of surfaces should be avoided, for the other methods of treatment are more reliable and usually much more satisfactory. Plastering, even if carefully applied, is likely to peel off under the action of frost or temperature changes.

DESIGN.

1. *Massive Concrete.* -- In the design of massive concrete or plain concrete no account should be taken of the tensile strength of the material, and sections should usually be so proportioned as to avoid tensile stresses. This will generally be accomplished, in the case of rectangular shapes, if the line of pressure is kept within the middle third of the section, but in very large structures, such as high masonry dams, a more exact analysis may be required. Structures of massive concrete are able to resist unbalanced lateral forces by reason of their weight, hence the element of weight rather than strength often determines the design. A relatively cheap and weak concrete will, therefore, often be suitable for massive concrete structures. Owing to its low extensibility, the contraction due to hardening and to temperature changes requires special consideration, and, except in the case of very massive walls, such as dams, it is desirable to provide joints at intervals to localise the effect of such contraction. The spacing of such joints will depend upon the form and dimensions of the structure and its degree of exposure.

Massive concrete may well be used for piers and short columns, in which the ratio of length to least width is relatively small. Under ordinary conditions this ratio should not exceed six, but where the central application of the load is assured a somewhat higher value may safely be used.

Massive concrete is also a suitable material for arches of moderate span where the conditions as to foundations are favourable.

2. *Reinforced Concrete.*—By the use of metal reinforcement to resist the principal tensile stresses, concrete becomes available for general use in a great variety of structures and structural forms. This combination of concrete and steel is particularly advantageous in the beam where both compression and tension exist; it is also advantageous in the column where the main stresses are compressive, but where cross-bending may exist. The theory of design will, therefore, relate mainly to the analysis of beams and columns.

3. The following are the principles of calculation—in abbreviated form—as recommended for the use of the designer :

PRINCIPLES.

A. *General Assumptions.*—(*a*) *Loads.*—The loads or forces to be resisted consist of :

1. *The dead load*, which includes the weight of the structure and fixed loads and forces.
2. *The live load* or the loads and forces which are variable. The dynamic effect of the live load will often require consideration. Any allowance for the dynamic effect is preferably taken into account by adding the desired amount to the live load or to the live load stresses. The working stresses, hereinafter recommended, are intended to apply to the equivalent static stresses so determined.

   In the case of high buildings the live load on columns may be reduced in accordance with the usual practice.

(*b*) *Length of Beams and Columns.*—The span length for beams and slabs shall be taken as the distance from centre to centre of supports, but shall not be taken to exceed the clear span plus the

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depth of beam or slab. Brackets shall not be considered as reducing the clear span in the sense here intended.

The length of columns shall be taken as the maximum unsupported length.

(*c*) *Internal Stresses.*—As a basis for calculations relating to the strength of structures, the following assumptions are recommended :

1. Calculations should be made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.
2. A plane section before bending remains plane after bending.
3. The modulus of elasticity of concrete in compression within the usual limits of working stresses is constant. The distribution of compressive stresses in beams is therefore rectilinear.
4. In calculating the moment of resistance of beams the tensile stresses in the concrete shall be neglected.
5. Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are, therefore, stressed in proportion to their moduli of elasticity.
6. The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete may be taken at 15.
7. Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

It is appreciated that the assumptions herein given are not entirely borne out by experimental data. They are given in the interest of simplicity and uniformity, and variations from exact conditions are taken into account in the selection of formulæ and working stresses.

For calculations relative to deflections the tensile strength of the concrete should be taken into account. For such calculations, also, a value of 8 to 12 for the ratio 6 the moduli corresponds more nearly to the actual conditions and may well be used.

B. Tee Beams.—In beam and slab construction an effective bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the beam, transverse reinforcement should be used extending over the beam and well into the slab.

Where adequate bond between slab and web of beam is provided the slab may be considered as an integral part of the beam, but its effective width shall be determined by the following rules :

(*a*) It shall not exceed $\frac{1}{4}$ of the span length of the beam ;

(*b*) Its overhanging width on either side of the web shall not exceed 4 times the thickness of the slab.

In the design of Tee beams, acting as continuous beams, due consideration should be given to the compressive stresses at the support.

C. Floor Slabs.—Floor slabs should be designed and reinforced as continuous over the supports. If the length of the slab exceeds 1·5 times its width the entire load should be carried by transverse reinforcement. Square slabs may well be reinforced in both directions.

The loads carried to beams by slabs which are reinforced in two directions will not be uniformly distributed to the supporting beam and may be assumed to vary in accordance with the ordinates of a triangle. The moments in the beams should be calculated accordingly.

D. Continuous Beams and Slabs.—When the beam or slab is continuous over its supports, reinforcement should be fully provided at points of negative moment. In computing the positive and negative moments in beams and slabs continuous over several supports, due to uniformly distributed loads, the following rules are recommended :

(*a*) That for floor slabs the bending moments at centre and at support be taken at $\frac{wl^2}{12}$ for both dead and live loads, where w represents the load per lineal foot and L the span length.

(*b*) That for beams the bending moment at centre and at support for interior spans be taken at $\frac{wl^2}{12}$, and for end spans it be taken at $\frac{wl^2}{10}$ for centre and adjoining support, for both dead and live loads.

In the case of beams and slabs continuous for two spans only, or of spans of unusual length, more exact calculations should be made. Consideration is also required in the case of concentrated loads.

Where beams are reinforced on the compression side, the steel may be assumed to carry its proportion of stress in accordance with the provisions above, see Section 3, c-6. In the case of continuous beams, tensile and compressive reinforcement over supports must extend sufficiently beyond the support to develop the requisite bond strength.

E. Bond Strength and Spacing on Reinforcement.—Adequate bond strength should be provided in accordance with the formula hereinafter given. Where a portion of the reinforcement is bent up near the end of a beam, the bond stress in the remaining straight reinforcement will be less than is represented by the theoretical formula.

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Where high bond resistance is required the deformed bar is a suitable means of supplying the necessary strength. Adequate bond strength throughout the length of a bar is preferable to end anchorage, but such anchorage may properly be used in special cases. Anchorage furnished by short bends at a right angle is less effective than hooks consisting of turns through 180°.

The lateral spacing of parallel bars should not be less than 2½ diameters, centre to centre, nor should the distance from the side of the beam to the centre of the nearest bar be less than 2 diameters. The clear spacing between two layers of bars should not be less than ½ in.

F. Shear and Diagonal Tension.—Calculations for web resistance shall be made on the basis of maximum shearing stress, as determined by the formulæ hereinafter given. When the maximum shearing stresses exceed the value allowed for the concrete alone, web reinforcement must be provided to aid in carrying the diagonal tension stresses. This web reinforcement may consist of bent bars, or inclined or vertical members attached to or looped about the horizontal reinforcement. Where inclined members are used the connection to the horizontal reinforcement shall be such as to insure against slip.

Experiments bearing on the design of details of web reinforcement are not yet complete enough to allow more than general and tentative recommendations to be made. The following allowable values for the maximum shearing stresses are therefore recommended, based on the working stresses given below :—

(*a*) For beams with horizontal bars only 40 lb. per sq. in.

(*b*) For beams in which a part of the horizontal reinforcement is used in the form of bent-up bars, arranged with due respect to the shearing stresses, a higher value may be allowed, but not exceeding 60 lb. per sq. in.

(*c*) For beams thoroughly reinforced for shear a value not exceeding 120 lb. per sq. in.

In the calculation of web reinforcement to provide the strength required under (*c*) above, the concrete may be counted upon as carrying one-third of the shear. The remainder is to be provided for by means of metal reinforcement consisting of bent bars or stirrups, but preferably both. The requisite amount of such reinforcement may be estimated on the assumption that the entire shear on a section, less the amount assumed to be carried by the concrete, is carried by the reinforcement in a length of beam equal to its depth.

The longitudinal spacing of stirrups or bent rods shall not exceed ¾ the depth of the beam.

It is important that adequate bond strength be provided to develop fully the assumed strength of all shear reinforcement.

Inasmuch as small deformations in the horizontal reinforcement tend to prevent the formation of diagonal cracks, a beam will be strengthened against diagonal tension failure by so arranging the horizontal reinforcement that the unit stresses at points of large shear shall be relatively low.

G. Columns.—It is recommended that the ratio of unsupported length of column to its least width be limited to 15.

The effective area of the column shall be taken as the area within the protective covering, as defined in "Construction," Section 4, or in the case of hooped columns or columns reinforced with structural shapes it shall be taken as the area within the hooping or structural shapes.

Columns may be reinforced by means of longitudinal bars, by bands or hoops, by bands or hoops together with longitudinal bars, or by structural forms which in themselves are sufficiently rigid to act as columns. The general effect of bands or hoops is greatly to increase the "toughness" of the column and its ultimate strength, but hooping has little effect upon its behaviour within the limits of elasticity. It thus renders the concrete a safer and more reliable material and should permit the use of a somewhat higher working stress. The beneficial effects of "toughening" are adequately provided by a moderate amount of hooping, a larger amount serving mainly to increase the ultimate strength and the possible deformation before ultimate failure.

The following recommendations are made for the relative working stresses in the concrete for the several types of columns :

(*a*) Columns with longitudinal reinforcement only, the unit stress recommended for axial compression in Section C below.

(*b*) Columns with reinforcement of bands or hoops, as hereinafter specified, stresses 20 per cent. higher than given for (*a*).

(*c*) Columns reinforced with not less than 1 per cent. and not more than 4 per cent. of longitudinal bars and with bands or hoops, stresses 45 per cent. higher than given for (*a*).

(*d*) Columns reinforced with structural steel column units which thoroughly encase the concrete core, stresses 45 per cent. higher than given for (*a*).

In all cases longitudinal reinforcement is assumed to carry its proportion of stress in accordance with Section A. The hoops or bands are not to be counted upon directly as adding to the strength of the column.

Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete has set.

Where bands or hoops are used, the total amount of such reinforcement shall be not less than 1 per cent. of the volume of the column enclosed. The clear spacing of such bands or hoops shall not

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be greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centred.

Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

H. Reinforcing for Shrinkage and Temperature Stresses.—The size of the cracks will be directly proportional to the diameter of the reinforcing bars and inversely proportional to the percentage of reinforcement and also to its bond resistance per unit of surface area. To be most effective, therefore, reinforcement should be placed near the exposed surface and well distributed, and a form in reinforcement used which will develop a high bond resistance.

WORKING STRESSES.

A. General Assumptions.—The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to produce an equivalent static load before applying the unit stresses in proportioning parts.

In selecting the permissible working stress to be allowed on concrete we should be guided by the working stresses usually allowed for other materials of construction, so that all structures of the same class but composed of different materials may have approximately the same degree of safety.

The stresses for concrete are proposed for concrete composed of 1 part Portland cement and 6 parts of aggregate, capable of developing an average compressive strength of 2,000 lb. per sq. in. at 28 days, when tested in cylinders 8 in. in diameter and 16 in. long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. In considering the factors recommended with relation to this strength, it is to be borne in mind that the strength at 28 days is by no means the ultimate which will be developed at a longer period, and therefore they do not correspond with the real factor of safety. On concretes, in which the material of the aggregate is inferior, all stresses should be proportionately reduced, and similar reductions should be made when leaner mixes are to be used. On the other hand, if, with the best quality of aggregates, the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent.

B. Bearing.—When compression is applied to a surface of concrete larger than the loaded area, a stress of 32·5 per cent. of the compressive strength at 28 days, or 650 lb. per sq. in. on the above-described concrete, may be allowed. This pressure is probably unnecessarily low when the ratio of the stressed area to the whole area of the concrete is much below unity, but is recommended for general use rather than a variable unit based upon this ratio.

C. Axial Compression.—For concentric compression on a plain concrete column or pier, the length of which does not exceed 12 diameters, 22·5 per cent. of the compressive strength at 28 days, or 450 lb. per sq. in. on 2,000 lb. concrete, may be allowed.

For other forms of columns the stresses refer to the ratios given in Clause G above.

D. Compression in Extreme Fibre.—The extreme fibre stress of a beam, calculated on the assumption of a constant modulus of elasticity for concrete under working stresses, may be allowed to reach 32·5 per cent. of the compressive strength at 28 days, or 650 lb. per sq. in. for 2,000 lb. concrete. Adjacent to the support of continuous beams stresses 15 per cent. higher may be used.

E. Shear and Diagonal Tension.—Where pure shearing stress occurs—that is, uncombined with compression normal to the shearing surface, and with all tension normal to the shearing plane provided for by reinforcement—a shearing stress of 6 per cent. of the compressive strength at 28 days, or 120 lb. per sq. in. on 2,000 lb. concrete, may be allowed. Where the shear is combined with an equal compression, as on a section of a column at 45° with the axis, the stress may equal ½ the compressive stress allowed. The ratios of compressive stress to shear intermediate between 0 and 1, proportionate shearing stress shall be used.

In calculations on beams in which the diagonal tension is considered to be taken by the concrete the vertical shearing stresses should not exceed 2 per cent. of the compressive strength at 28 days, or 40 lb. per sq. in., for 2,000 lb. concrete.

F. Bond.—The bonding stress between concrete and plain reinforcing bars may be assumed at 4 per cent. of the compressive strength at 28 days, or 80 lb. per sq. in. for 2,000 lb. concrete, in the case of drawn wire 2 per cent., or 40 lb. on 2,000 lb. concrete.

G. Reinforcement.—The tensile stress in steel should not exceed 16,000 lb. per sq. in. The compressive stress in reinforcing steel should not exceed 16,000 lb. per sq. in., or 15 times the working compressive stress in the concrete.

In structural steel members the working stresses adopted by the American Railway Engineering and Maintenance of Way Association are recommended.

H. Modulus of Elasticity.—The value of the modulus of elasticity of concrete has a wide range, depending upon the materials used, the age, the range of stresses between which it is considered, as well as other conditions. It is recommended that in all computations it be assumed as one-fifteenth that of steel, as, while not rigorously accurate, this assumption will give safe results.

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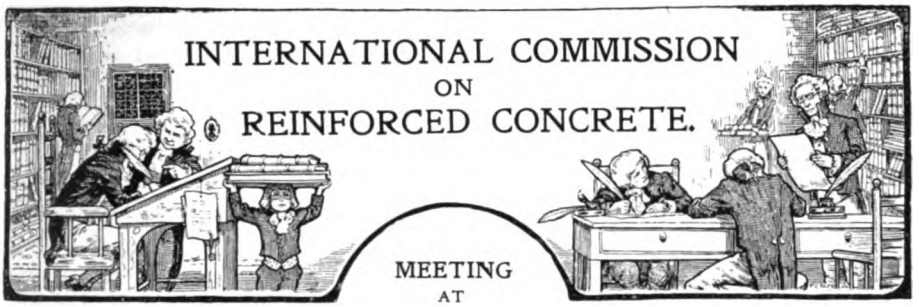

COPENHAGEN.

It affords us considerable pleasure to record that a further meeting of the International Commission on Reinforced Concrete has taken place. This meeting, which was held at Copenhagen, marks another step forward in the question of standardisation and uniformity in matters relating to the scientific aspect of the new material.

It was pleasant to observe that Great Britain was not—as is so frequently the case on International commissions—entirely in the background at this particular conference. It was, however, a matter of remark that the Institution of Civil Engineers, who had appointed a delegate and are at present considering certain questions of research in reinforced concrete, neither sent their delegate nor a deputy on his behalf. Omissions of this kind are neither beneficial to the subject under review, to the standing of the country concerned, nor to the institution referred to.—ED.

THE International Commission on Reinforced Concrete met at Copenhagen on Monday, September 6th, the meeting having been called on the occasion of the Conference of the International Association for Testing Materials, which was being held at that time in the Danish capital.

We have on a previous occasion * published particulars of the constitution of this Commission, which is thoroughly representative of the various countries concerned, and it is interesting to note that of the present membership of 37, no less than 25 members, representing 12 countries, attended the meeting.

The chairman of the Commission, Professor F. Schüle, of the Zurich Polytechnic, presided, and both the vice-chairmen, Privy Councillor Germelmann, of the Ministry of Public Works, Berlin, and Professor A. W. Talbot, of the Illinois University, U.S.A., attended. The British delegates present were Mr. Edwin O. Sachs, F.R.S.Ed. (chairman of the British Fire Prevention Committee), Mr. William Dunn, F.R.I.B.A. (chairman of the Science Committee of the Concrete Institute), and Mr. W. Kirkaldy, Assoc.M.Inst.C.E., acting as deputy for Mr. Max Clarke, F.R.I.B.A., who was unable to be present. The fourth British representative, Professor Unwin, LL.D., M.Inst.C.E., who had been recently elected as the representative of the Institution of Civil Engineers, was unfortunately unable to attend, nor was a deputy present on his behalf.

The work of the Commission might be summarised by saying that it is intended to collect and epitomise the results of tests and investigations on reinforced concrete conducted in the different parts of the world; to standardise methods of testing and the form in which reports of tests are to be issued; to record failures, if any; to summarise their causes and finally to obtain, if possible, some international method for algebraical notation in presenting calculations for reinforced concrete. It is also intended to prepare a guide for the future conduct of tests and to define the nature of tests still required.

What with the divergence of interests, the difference of practice, and last, but not least, the variety of language, it is obvious that, as in the case of most

* CONCRETE AND CONSTRUCTIONAL ENGINEERING, Vol. II., No. 2.

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international commissions, the work that has to be executed must make but slow progress, and will be fraught with difficulty; but, apart from any formal work done at the meetings of the Commission, it is clear that the opportunity the conference affords for those interested in kindred subjects to meet and discuss questions of mutual interest must have a most important bearing on the development of reinforced concrete generally. Thus, to take one small instance alone, it is unlikely that either the British or Continental members of the Commission would have had an opportunity of discussing matters with that great American authority on testing reinforced concrete, Professor Talbot, of Illinois, had it not been for the Copenhagen meeting.

So far as the actual work done by the Commission is concerned, progress has been made by obtaining particulars from some of the different countries as to the tests already undertaken, and the programme of tests in hand, which particulars will be presented in these columns as they are issued.

Further suggestions have been made as to algebraical notation for calculations in reinforced concrete, and the representatives of the different countries of the Continent of Europe have already agreed as to what notation should be adopted so far as their countries are concerned. An effort will now be made by the British and American institutions to agree, firstly, if possible, to some mutual form of notation, and, secondly, in an effort to bring their proposals into line, or as nearly as possible into line, with those of the Continent. No doubt the Concrete Institute and the Joint Committee on Reinforced Concrete in the United States will soon arrive at an understanding.

To those who have to make reports and investigations in different countries the extraordinary divergence in the manner of presenting these reports has been a constant source of inconvenience, and Professor Schüle is now presenting a standard form of report which, no matter how the report be drafted locally, would in a few lines summarise the object and the results of tests in a uniform manner, and either be appended to or preface the local report.

An effort will also be made to accelerate the presentation of a schedule of the tests undertaken or in course of execution in other countries in which they have not yet been issued, and it was resolved that these results should be summarised in such a form that one could clearly see what had been done in the way of tests throughout the civilised world, and from those results gauge what investigations are still missing. This work alone should spell economy for those engaged in research, for the extraordinary amount of repetition that occurs in testing in connection with reinforced concrete has almost become a scandal.

We understand that there will be annual meetings of the Commission, those of 1910 and 1911 to be held in Europe, and that of 1912 in the United States. It is to be hoped that with the progress this country is now making in matters relating to reinforced concrete one of the meetings intended to be held in Europe may take place in this metropolis, for there is no doubt that meetings of this kind, apart from their direct utility and the opportunity they afford for the members to meet, indirectly influence the development of the subject locally. The technical and governmental interest in reinforced concrete is also increased

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by the mere fact that such conferences are ocular demonstrations of the importance given to the subject by those persons of different countries best able to gauge the necessity of investigation and research.

In conclusion, it should be mentioned that at the Conference of the International Association for Testing Materials a suitable resolution was proposed by Mr. Sachs, recommending the attention of the public authorities and institutions concerned to the work being undertaken by the International Commission on Reinforced Concrete, with a view to their granting not only technical but also financial assistance, and this resolution was unanimously adopted.

We note with satisfaction that both the chairman and vice-chairman remain in office, and it is probable that the Committee will be strengthened by an additional member—namely, Mr. Richard L. Humphreys, the secretary of the Joint Committee on Reinforced Concrete in the United States.

SUMMARIES OF TESTS UNDERTAKEN.

THE International Commission has issued some of the reports on the steps that have been taken in different countries towards making systematic investigations of the properties of reinforced concrete. The reports now presented, which we summarise below, are in part records of work already done, and in part programmes of work which it is intended to carry out in the near future. They offer a double interest, as describing the nature of the tests regarded by competent authorities as of importance, and also as indicating the forms taken by the organisation of research in reinforced concrete in different countries. The summarised translations presented have been specially prepared for this journal by Mr. Cecil H. Desch, D Sc., from the French or German originals.

GERMANY.

The German Committee for Reinforced Concrete, called into existence in 1907 at the instance of the Prussian Minister of Public Works, consists of representatives of the German Empire and of the larger German States, the directors of all the German technical testing stations, delegates from the Union of German Architectural and Engineering Associations, the German Concrete Association, the Association of German Portland Cement Manufacturers, and the Association of German Ironmasters, and of other experts in reinforced concrete. This Committee is now engaged in planning and executing tests in accordance with the three following schemes :—

SCHEME I.—Tests with plain concrete. (*a*) Compressive tests, including the measurement of total and permanent deformations; (*b*) bending tests, including the influence of dimensions of test-pieces; (*c*) tensile tests, including alternations of tension and compression; (*d*) torsional, and (*e*) shearing tests.

Mixtures in two different proportions of two different and characteristic sands and aggregates are to be used. Compressive tests to be made with two cements and two proportions of water. Sand, crushed stone, and crushed slag are to be compared together. The test-pieces are to be grouped, some in 3, some in 5 classes, according to age, namely, 28 days, 90 days, and 1, 2 and x years.

SCHEME II.—Behaviour of steel in concrete and masonry, to determine (*a*) whether the corrosion of steel depends on the material in which it is embedded; (*b*) what degree of adhesion exists between steel and mortar; (*c*) the influence of the character and treatment of the surface of the steel and of its distance from the surface of the concrete; (*d*) whether chemical union between steel and mortar is to be assumed.

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For this purpose, three series of experiments are being made: *(a)* Tests of adhesion and corrosion in brickwork and rubble masonry with different mortars, set in air; *(b)* rusting and chemical behaviour of steel in small masses of mortar; *(c)* resistance to corrosion, and if necessary of adhesion, of steel rods in test-pieces prepared with different mortars, set in air and in different waters.

SCHEME III.—This was drawn up by the Reinforced Concrete Committee of the International Association for Testing Materials, and is very comprehensive. It is given below in detail.

I. GENERAL TESTS.

A. Tests of Adhesion and Corrosion.—(a) Preliminary.

1. Influence of percentage of water, nature of sand and aggregate, and proportions of mixture.

2. Influence of surface of steel. Tensile and bending tests with round steel bars of different section, polished; with skin due to rolling but free from rust; cleaned from loose rust; rusty; and painted with cement. Comparison of round, angle, flat, and profiled bars of equal surface.

3. Influence of insufficient covering of the steel. Tensile tests with the rods near the centre and close to the surface, and bending tests with the rods close to the lower surface, and with rods insufficiently spaced.

4. Influence of hardening in air, in water, during frost, or while exposed to heat or steam.

5. Influence of shaking during preparation and setting on the adhesion.

6. Influence of different modes of loading—namely, gradually increasing loading, repeated loading, sudden loading, long-continued loading.

7. Protection against rust in complete members, reinforced concrete plates with clean and rusty iron being kept under unfavourable conditions and subsequently loaded.

(b) ***Principal Experiments.***—1. Determination of the adhesion by direct pulling.

2. Adhesion during the bending of plates and plate beams.

B. Resistance to Tension of Reinforced Concrete.—Tests with rectangular beams and plate beams. Determinations of subsidiary stresses. Influence of different percentages of reinforcement, distribution of the steel areas, mixtures, and percentages of water. Hardening in air and water, exposed to heat radiation on one or all sides. Different conditions of loading. Comparison with plain concrete. Examination of the factor of safety prescribed by the Prussian Regulations for the appearance of tension cracks.

C. Resistance to shearing stresses, using rectangular beams and plate beams with differently distributed main reinforcement and stirrups.

D. Influence of anchoring and similar precautions: (1) Overlapping of the bars; (2) overlapping, the ends being hooked; (3) the same, the bars being wrapped with wire; (4) direct hooks; (5) plates on ends of bars; (6) enlargements; (7) welded ends.

II. SPECIAL TESTS WITH STRUCTURAL MEMBERS.

A. Beams and Plates.—1. Beams and plates with simple reinforcement, rectangular outline, freely supported on two sides. Control of the method of computation. The modes of support to be distinguished are: completely freely supported; freely supported, but enclosed at sides; partial and complete fixing; and connection of beams and supports to form frames.

2. Plates of rectangular section, doubly reinforced, freely supported on two sides.

3. Square and rectangular plates, freely supported on all sides. Establishment of a method of computation. Computation when the reinforcement is diagonal.

4. Plates having all four sides partly or completely fixed.

5. Plates continuous over three supports: *(a)* rigid supports, equal spans, beams free to rotate; *(b)* elastic supports, equal spans, beams free to rotate; *(c)* rigid supports, equal spans, beams not free to rotate, partly fixed; *(d)* continuous plates on freely supported reinforced concrete beams; *(e)* continuous plates on freely supported I beams, with partial stressing of the upper flanges of the beams.

6. As in 5, but with unequal spans.

B. Tests with Plate Beams.—1. Simple plate beams: *(a)* Influence of the width of plate, action of the plate in resisting compression, control of the existing methods of computation; *(b)* influence of the ratio of thickness of plate to breadth of plate and depth of web on the resistance to compression; *(c)* influence of stressing the plate in two directions perpendicular to each other on the resistance to bending. Comparison with a simply stressed beam; *(d)* framing beams examined as with *(a)*; *(e)* plate beams with web directed upwards to determine the value of a reinforcement to resist compression on the upper side of the web.

2. Framing beams, so disposed that the compressive stresses in the flooring panel are additive. Box floors.

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3. Continuous panelled floors, with three rigid supports, equal spans, beams free to rotate, plate beams with and without vaulting. Plate beams with variously arranged reinforcement.

C. Tests with Columns.—1. Preliminary experiments to determine the value of different forms of transverse ties.

2. Influence of the distribution of the steel section in transverse ties.

3. Influence of size of ties.

4. Main experiments, with transverse reinforcement consisting of (*a*) stirrups; (*b*) spirals and hoops; (*c*) stirrups without longitudinal reinforcement; (*d*) determination of resistance to bending.

Further Experiments.—Experiments are also proposed to determine the resistance to fire, and the behaviour towards electric currents.

Control of Reinforced Concrete Work.—The tests made in connection with the control of the execution of reinforced concrete works in Germany are conducted on plain concrete cubes, the present regulations fixing their size at 30 cm. (nearly 12 in.) side. Further regulations as to tests during execution of works are under consideration.*

ITALY.

Development of Testing Laboratories.—The Italian report, drawn up by M. Benetti, of Bologna, refers to the great development of testing laboratories within the last few years. In Italy a National Association for Testing Materials is in existence, and each province has a laboratory, which may be used by public authorities or private clients on the payment of fees according to a fixed scale. The Administration of State Railways has established a central testing laboratory in Rome under M. C. Segré, and the other laboratories (the names of their directors being added in parentheses) are attached to the Engineering Schools of Palermo (M. G. Salemi), Naples (M. E. Isé), Rome (M. C. Ceradini), Bologna (M. S. Canevazzi), Padua (M. V. L. Rossi), Milan (M. A. Sayno), and Turin (M. C. Guidi), the Naval School of Genoa (M. M. Panetti), and the Technical Institute of Florence (M. G. Bellotti).

Work of the Laboratories.—Most of these laboratories have been rapidly equipped for the purpose of making the officially prescribed tests, but several are also capable of undertaking scientific investigations. Several series of experiments have been issued by the State Railways Laboratory in two collected reports (published by G. Civelli, Rome, 1906 and 1908). Further, all the laboratories have made tests with a view to fixing a standard sand, and the Bulletin of the Italian Association has contained several researches bearing on reinforced concrete, namely:—A memoir on granulometry by M. G. Salemi; M. Greco's experiments on the resistance of mortar and concrete to shear, and those of MM. S. Canevazzi and A. Landini on the influence of the mode of preparation of the test-piece, and of the use of dry and plastic mortars in laboratory tests.

Such tests as have been made with reinforced concrete have mainly had an industrial object, but the Railway Laboratory has investigated the strength of piles, and at Bologna a comparison has been made between plates reinforced with bars and with expanded metal, whilst M. Panetti has investigated at Genoa the resistance of cylinders and reservoirs. Resistance tests have been made by M. Rossi at Padua, and General Caveglia and Colonel Marzocchi have made valuable tests for military purposes.

Experiments.—A systematic series of experiments has been conducted since 1900 by Prof. C. Guidi, of the Turin Polytechnic, on the adhesion of concrete to steel, on elasticity under traction, compression and bending, and on the influence of the reinforcement in pieces in compression. During 1905-1906 he made a series of 300 tests at the instance of a committee of the Turin Society of Engineers, including tests with large columns and beams as well as with laboratory specimens. The influence of frost, and of the stresses developed in the steel during the hardening of the concrete, were among the new factors studied. In 1906 M. Guidi published a comparison of the different means of joining reinforcing rods: ordinary welds, oxy-acetylene welds, screwed sleeves, adhesion joints (superposition or folding for a length of 30 diameters). At the present time he is making tests on large beams reinforced with American bars.

* The Prussian Rules of 1904 are summarised in this Journal, No. 3, Vol. III.

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Control, etc.—Until recently the regulations for the control of reinforced concrete work were not uniform throughout Italy. As a rule contracts were executed by firms of specialists, and the test applied before passing the work consisted of loading short of the production of cracks, the load often being 1½ times the working load, with the provision that the deflection should not exceed one-thousandth of the span. This empirical plan was discussed by the Italian Association, which ultimately presented a scheme of regulations for reinforced concrete work, which was discussed in the Perouse Congress of 1906, and subsequently accepted by the Italian Government, being made official by Ministerial decree of January 10th, 1907. Since that time the specifications of public authorities and private firms have tended to become more uniform, and will probably become entirely so. They generally require a complete description of the structure to be erected, with a computation of stresses based on the higher limit theory of Canevazzi, that is, assuming (1) the principle of the conservation of plane sections; (2) the proportionality of the internal stresses to the distance of each element of resisting surface from the axis of rotation of the section, on the hypothesis that the metal resists tension and compression equally, that the concrete resists compression only, and that the ratio m of the two moduli of elasticity is constant and equal to 10. In the case of simple tension or compression, the axis of rotation removes to infinity, that is, the stress is uniformly distributed over the effective section.

Finally, the official regulations impose a thorough control of the quality of the materials employed, and of the workmanship, by means of tests in an official laboratory. Before the structure is passed, a loading test must be made, no cracks appearing and the deformation not exceeding the theoretical value.

The maximum load per unit area permitted for concrete is 1-5th the breaking load under compression, determined on cubes of 12 cm. (4½ in.) side, 28 days old.

DENMARK.

The Danish report, drawn up by Prof. Suenson, of Copenhagen, deals mainly with experiments by Captain Grüt on the thermal conductivity of concrete, published in 1903. As data on this point are comparatively scanty, the results obtained may be reproduced here :—

Results.—Two hollow cylinders, 51 cm. (20 in.) high, 34 cm. (13½ in.) external and 14 cm. (5½ in.) internal diameter were prepared with a 1 : 1½ : 1½ and a 1 : 2 : 3 mixture respectively, the aggregate being gravel. The inside being heated electrically to 1000° C. (1832° F.), the temperatures at a distance of 1, 2, 3, 5, 7, and 9 cm. (0·39, 0·79, 1·18, 1·97, 2·75, and 3·54 in.) from the inner surface were measured every half hour by means of a Le Chatelier platinum-rhodium thermocouple. After 7 to 8 hours equilibrium was attained, the temperatures then being :—

at	0	1	2	3	5	7	9 cm.
	1004°	834°	679°	600°	449°	348°	264° C.
or	0	0·39	0·79	1·18	1·97	2·75	3·54 in.
	1841°	1532°	1250°	1112°	842°	658°	475° F.

these values being the mean of those obtained with the two cylinders. Supposing a floor to be heated from below in a conflagration, the reinforcing steel is in a similar position to the pyrometer 2 cm. from the inner surface. The temperature at this point rose as follows :—

after	1	2	3	4	5	6	7 hours
	259°	424°	537°	601°	637°	659°	675° C.
	498°	797°	1000°	1113°	1180°	1220°	1247° F.

The cylinders were three months old, but one of them had been heated internally to 1000° C. and again cooled before the experiment. This treatment, by expelling the water, raised the conductivity, so that this cylinder was throughout an hour in advance of the other in temperature.

A number of concrete cubes were heated to different high temperatures and tested by compression after cooling. The blocks had hardened a week in water and 2½ to 3 months in air. The results obtained were :—

Heated to :—							
Room temperature	100°	150°	200°	300°	500°	700°	1000° C.
	212°	302°	392°	484°	932°	1292°	1832° F.
Broke at :—							
373·9	370·1	425·3	424·2	379·2	304·6	171·3	47·1 atmospheres.
5600	5550	6390	6370	5690	4750	2590	705 lb. per sq. in.

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Corrugated Bar Tests.—Prof. Suenson has made tests with Johnson's corrugated bars (1908), and finds that, if the length of bar embedded is sufficient, corrugated bars may be stressed to the breaking limit, whilst it is impossible to stress round bars beyond the elastic limit if the ends are not anchored. Plates reinforced with 0·2 to 0·7 per cent. of steel showed a breaking load 36 to 40 per cent. higher with corrugated than with round bars, but the formation of cracks took place under the same load in both cases.

Control of Reinforced Concrete Work.—The control of reinforced concrete work during construction is generally performed in Denmark by tests on small beams, 200 by 6 by 9 cm. (6 ft. 6¾ in. by 2·4 in. by 3·5 in.) reinforced by two 7 mm. (0·27 in.) round bars with bent ends, so placed that the centre of the iron is 1 cm. (0·39 in.) from the lower surface of the beam. After 28 days the beams are loaded, the span being 180 cm. (5 ft. 11 in.), and the breaking load must not be less than 4·5 σ_b, where σ_b is the permissible compressive stress in the concrete, assumed by the designer in his computations.

HOLLAND.

The Dutch report, drawn up by Mr. S. J. Rutgers, of Rotterdam, contains an account of a large number of tests, indicating considerable activity in that country in the field of reinforced concrete construction.

I. BENDING TESTS.

A. Statically Indeterminate Structural Members.—1. Loading tests were made on 21 arches of the reinforced concrete railway viaduct at Rotterdam, with spans of 7·5 to 20 metres (27 ft. 6 in. to 65 ft. 7 in.), and on four bridge arches of 20 metres span on the Maastricht-Aachen Railway at Limburg. The observed and calculated deflections were compared (see *De Ingenieur*, 1907 and 1908).

2. A footbridge, 29 m. (95 ft. 1 in.) span, over the Lusthofstraat in Rotterdam, was tested for temporary and permanent deformation, 8 instruments of the Manet-Rabert pattern being used (see *De Ingenieur*, 1902).

3. Two constructional elements of the bridge over the Hoogen Boezem at Rotterdam were specially prepared for testing. The span was 6·55 m. (21 ft. 6 in.). Temporary and permanent deformations were measured by six instruments of Schroeder van der Kolle's pattern.

4. In the building of a barrack at Ede a panel, prepared by Messrs. F. J. Stulemeyer, was tested, resting on four supports, 3·31 m. (10 ft. 10 in.) from centre to centre. The panel was 1 m. broad (3 ft. 3 in.), and reinforced with 15 rods 10 mm. (0·39 in.) dia. Loading was continued to destruction.

B. Flat Plates and Rectangular Beams.—1. The oldest experiments are due to Messrs. Tutein Nothenius, from 1894 onwards a number of plates, reinforced in various ways, being tested to destruction after measuring deflections under various loads. The influence of the composition and age of the concrete was also examined.

2. Since 1896 Mr. L. A. Sanders has also conducted tests with beams and panels, comparing different modes of reinforcement, etc. Particulars of some of these may be omitted, as they do not differ in any important respect from other tests, but one series may be described. In the erection of a military administrative building at Zuidwykermeer three panels were tested, each of which was 13 m. by 1 m. by 25 cm. (42 ft. 7 in. by 3 ft. 3 in. by 0·8 in.) reinforced with 16 bars of 16 mm. (6·3) dia. on the upper as well as the under side. The supports were 5 m. (16 ft. 4 in.) from centre to centre, so that by loading the overhanging ends negative moments could be produced over the supports. One panel was without stirrups, the others having 32 and 64 per sq. metre respectively. In all cases fracture occurred near a support, the breaking loads being in the ratio 2·03 : 1·07 : 1, the highest being that without stirrups, and the lowest that with the largest number of stirrups (see remarks by Dr. von Emperger in *Beton und Eisen*, 1903, p. 262).

A few further tests are recorded without details of the results.

C. T-Beams.—Experiments were made by Mr. L. A. Sanders with :

1. Two T- and two ⊥- beams of similar dimensions and reinforcements, tested to destruction.

2. A large T-beam for the Gorinchem barracks of 7 m. (23 ft.) span and flange 1·40 m (4 ft. 7 in.) wide.

3. Several beams of somewhat smaller span for the Town Hall of the Hague, the Technical High School at Delft, etc., all being tested to destruction after measurement of the deflections under successive loads.

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II. OTHER TESTS.

Compression Tests.—The same investigator tested 36 prisms with different kinds of cross reinforcement, varying from 0·7 per cent. to 4·2 per cent. by volume.

Shearing Tests.—A series of 12 concrete blocks, 30 by 30 by 12 cm. (12 by 12 by 4¾ in.) were provided with round iron rods having a sharp angular screw thread cut on them. On pulling out, mortar remains in the threads, so that the test is one of shearing.

Mr. A. C. C. G. van Hemert has also calculated the shearing stress from torsional experiments on concrete cylinders 20 by 20 cm. (8 in.), the ends being formed by 20 cm. cubes, to which the turning moments were applied.

Adhesion Tests.—Tests similar to those under III. were made, in one case smooth rods being drawn out of concrete cubes; in the other a rod 25 mm. (1 in.) in dia. was embedded in a concrete 20 cm. (8 in.) cube, the projecting ends being clamped and a torsional moment applied to the cube.

Tests of Expansion and Thermal Conductivity of Concrete.—Mr. Hemert has also tested a beam 3 m by 18 cm. by 12 cm. (9 ft. 10 in. by 7 in. by 4¾ in.), drilled with holes reaching to the centre, in which thermometers were inserted, contact being made by mercury. The temperature of the room was slowly raised from 26° to 34° C. (79° to 93° F.), and the longitudinal expansion measured. For conductivity tests beams of similar dimensions were passed through the wall of a room, heated by a fire at the outer end, and the temperatures at the inner end read from time to time (see *De Ingenieur*, 1904).

Tests Relating to Hair Cracks.—Important experiments were made by Mr. P. A. M. Hackstroh, who used beams bent from below, so that the surface in tension was uppermost. At a given load the surface was painted with a dilute solution of an aniline dye. On removing the load the cracks became very visible by the forcing out of the contained dye. After destruction the depth to which the dye had entered could be observed.

Mr. van Hemert improves on this by keeping the surface continually moist with the dye during loading. At the moment that a hair-crack appears the dye is projected laterally. The test is continued as in the original method.

Tests of the Action of Sea Water.—Mr. H. Wortman made tests on four beams suspended from the landing stage at Ymuiden, the beams being under a constant load from the middle point, the concrete being alternately covered and uncovered by the tide. After two and three years the beams were broken up, and, except for a few isolated specks, the reinforcing rods were found to be free from rust. The two beams of greatest age were broken up and examined in the presence of the committee for establishing standards for reinforced concrete in Holland.

Tests of the Action of Oil and Tar.—Mr. Wouter Cool made experiments with reinforced blocks, 20 by 5 by 5 cm. (8 by 2 by 2 in.), the reinforcing rods projecting. These were exposed to water-gas oil and water-gas tar for 2 years, and the blocks then tested for adhesion. Tar, and still more noticeably oil, was found to lessen the adhesion considerably.

Control of Reinforced Concrete during Construction.—In Holland the testing of some portion of the completed structure is sometimes prescribed. As a rule, the time elapsing before testing is optional, and the amount of load and maximum deflection varies. For example, in Rotterdam the deflection must not exceed 1/800 of the span under a load of 0·8 of the dead load + 1·8 of the live load.

In some cases compression tests on cubes of the concrete used are required, the size being usually 30 cm. cube (12 in.). In erecting important structures, the preparation of special structural members, corresponding statically as closely as possible with the works in course of execution, is demanded. Testing is then continued to destruction, a bending diagram being taken.

SWITZERLAND.

Prof. F. Schüle, of Zürich, who presents the report for Switzerland, states that until 1900 such tests of reinforced concrete in that country as were made were due to private initiative, and were intended to make known the advantages of various systems. In 1899 the Swiss Association of Engineers and Architects and the Association of Cement Manufacturers formed a committee for the systematic and independent study of that material, and in 1905 this committee became official, its members being appointed by the Federal Government, the Association of Swiss Municipalities, and the Societies named. The Committee has aimed at producing standard specifications based on tests, which have been carried out at the Federal Laboratory for Testing Materials at Zürich. These tests, many of which have been described in detail in former issues of CONCRETE, may be grouped as follows :—

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I. TESTS OF THE COMPONENT MATERIALS.

(*a*) ***Steel.***—Tests of the resistance of hooked ends of round steel bars, bent cold or hot at various radii.

(*b*) ***Concrete.***—Relation of the mechanical properties to the character of the sand and gravel.

The sand and gravel were supplied by Swiss towns. Two Portland cements were used in three different proportions. The concrete was mixed in a plastic state, and rammed to form prisms 12 by 12 by 6 cm. ($4\frac{3}{4}$ by $4\frac{3}{4}$ by $2\frac{3}{16}$ in.). The tests were made by bending and crushing at the ages of 28 days, 3 months, 1 year, and 2 years. Elastic measurements were also made.

(*c*) ***Mortar and Concrete.***—The variations in length during hardening in air and in water have been studied, the tests being continued over 2 years. The prisms were prepared from mortars (1) with 5 different materials, in the ratios 1 : 0 and 1 : 3; (2) with 2 different materials, in the ratios 1 : 1, 1 : 3, and 1 : 5; and from concretes with 2 different materials in the proportion of 150, 300 and 450 kg. per cub. metre of sand and gravel (253, 506, and 759 lb. per cub. yd.).

II. TESTS OF REINFORCED CONCRETE.

(*a*) Most of the tests have been made with beams subjected to bending, observing the load corresponding with each phase of fatigue, the breaking load, the effect of removing the load, the variations of length, especially in the compression zone, in order to fix with certainty the position of the neutral axis, and the deflection at the middle point.

The following forms of loading were used :—

I. A single load in the middle.
II. A load acting at two points placed symmetrically.
III. A load acting at seven points distributed over the length of the beam.
IV. An asymmetric load acting at four points distributed over one-half of the length.

Some of the beams were of rectangular section, others of T-form, reinforced with straight bars or with bars turned up at the ends, with or without stirrups.

In calculating the percentage of metal in relation to the area of concrete in the section or in the section of the web produced upwards in T-beams, tests have been made with reinforcement up to 4·91 per cent. in rectangular beams and 4·33 per cent. in T-beams, calculated as above.

(*b*) The action of a concentrated charge on a reinforced plate has been determined by tests: (1) on square panels of 1 m. (3 ft. 3 in.) free opening, supported on all four sides or on two sides, reinforcement 0·77 per cent. and 0·43 per cent. in both directions, and 1·54 and 0·86 per cent. in one direction only; (2) on rectangular panels 1 by 1·5 m. (3 ft. 3 in. by 4 ft. 11 in.) free opening, supported either on all sides or on the two long sides with reinforcement:

0·59 per cent. longitudinal and transverse.
0·32 per cent. longitudinal and transverse.
0·77 per cent. transverse; 0·30 per cent. longitudinal.
0·43 per cent. transverse; 0·17 per cent. longitudinal.

(*c*) The distribution of the stress over the width of a plate compressed by a force applied over a width equal to the thickness of the plate has been studied by tests on prisms 1 and 1·5 m. high and of width varying from 12 to 96 cm. ($4\frac{3}{4}$ to $37\frac{3}{4}$ in.). The deformation was measured at a number of points on the width in the median section. Some of the plates were transversely reinforced, others of plain concrete.

(*d*) Tests of hollow reinforced concrete masts of truncated conical section, the test-pieces being cut from electric tramway poles. The percentage of reinforcement varied from 0·57 to 4·36 per cent. of the area of concrete in a section at half the height.

III. TESTS OF COMPLETE REINFORCED CONCRETE STRUCTURES.

These tests were undertaken at the time of approval of various structures. They consisted in the measurement of the deflection at a number of points during loading, enabling determinations to be made of the degree of fixing and of continuity of the principal beams.

Usual Control of Reinforced Concrete.—The specifications prescribe tensile tests of the steel. For concrete, Swiss standard tests of the Portland cement are required at 7 and 28 days, and tests of a series of cubes or prisms, generally four in number, cubes 28 cm. (11 in.) side, prisms 36 cm. (14 in.) long and 12 cm. ($4\frac{3}{4}$ in.) square. The latter are tested by bending, and the broken halves are crushed between steel plates 12 cm. wide, placed crosswise.*

How extensive these tests are is shown by the fact that in 1908 more than 500 kinds of concrete were tested in the Zürich laboratory. The results show a steady improvement in the quality of the concrete, due to judicious proportioning of the sand and aggregate.

* The Swiss recommendations of 1903 are summarised in this journal, No. 3, Vol. III. Rules have since been promulgated.

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The Dam here described is partly of rubble masonry in Portland cement and partly in Portland cement concrete. It is an instructive example of the application of Portland cement and is presented as such with some useful technical detail.—ED.

THE city of Sydney, N.S.W., Australia, is at last assured against a water famine, now having a water supply for its growing population, which at the present time is about 600,000. The great cataract dam is completed, and the supply is derived from the Nepean and Cataract rivers.

The catchment area of 354 sq. miles, with the good rainfall, which is characteristic of the coastal districts of New South Wales, is ample for the requirements of the city, even supposing enormous expansion, but the existing storage at Prospect (only 5,446,000,000 gallons by gravitation) is quite inadequate, and further, as the water from the rivers mentioned is conveyed to Prospect by a system of canals and tunnels, having a daily capacity of only 150,000,000 gallons, the storm flow of the rivers cannot be fully availed of, and must be increased shortly.

In 1902 severe droughts occurred, and the Prospect reservoir was drawn on to such an extent as to cause anxiety as to the supply. Owing to this, and to the concurrent steady increase in the population of the city and suburbs, serious shortage of water was feared, and though the citizens of Sydney were never placed on a limited supply, except in the matter of water for ornamental gardens occasionally, it was felt that, in view of the future, more of the water available during rainy years must be impounded for the city supply. For that reason, therefore, the masonry and concrete dam has been erected on the Cataract River, with a storage capacity of 21,411,500,000 gallons.

The body of the Cataract Dam is composed of Cyclopean rubble masonry, consisting of blocks of sandstone weighing from 2 to 4½ tons, built to break joint both vertically and horizontally, and to have a maximum of bond. The stones are bedded in cement mortar, and the vertical joints are made with concrete. The proportion of blocks to concrete and mortar is approximately as 65 to 35. The up-stream face consists of concrete blocks 5 ft. × 2 ft. 6 in. × 2 ft., set upon and jointed with special cement mortar, and backed by an average of 3 ft. of basaltic concrete. The down-stream face is of concrete 6 ft. thick; the foundations of the dam have been carried to a depth of 35 ft. below the bed of the river in solid sandstone rock. Reinforced concrete is used in the construction of the valve chambers at the base of the dam.

The following figures give the main dimensions:—

Length of dam	811 ft.
Height above river bed	157 ,,
Depth below river bed	35 ,,
Total height from base to top (maximum)	192 ,,
Top width	16½ ,,
Bottom width	158 ,,
Maximum depth of the water stored	150 ,,
Total storage capacity	21,411 500,000 gals.
Area covered by water (approximate)	2,400 acres

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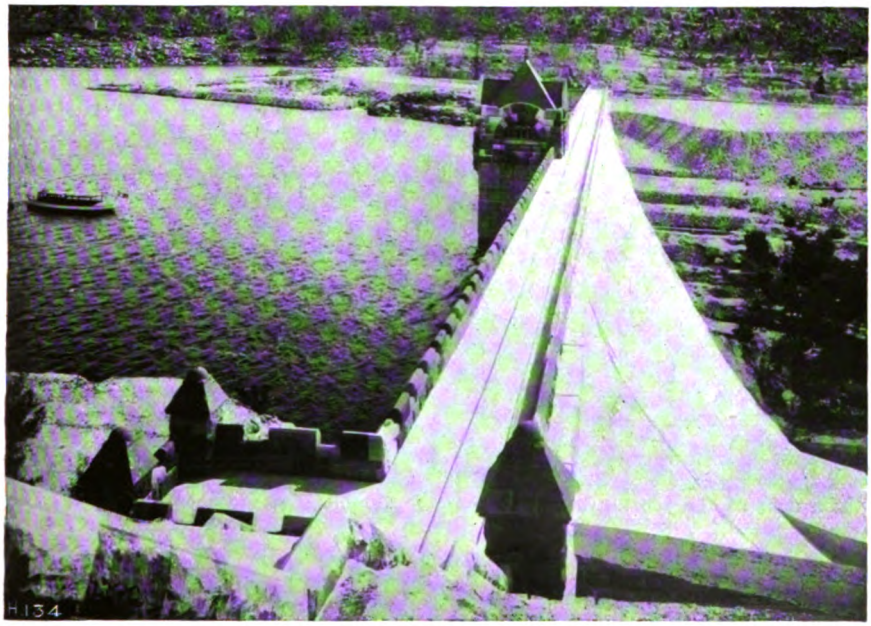
Material in dam as completed :—

Hearting masonry	111,455	cub. yds.
Rubble masonry	1,975	,,
Concrete	23,846	,,
Facing blocks	8,966	,,
	146,242	,,
Total Portland cement used	19,000	tons
Quantity of excavation in connection with works, foundations, bywash, etc.	215,000	cub. yds.
Ironwork in pipes, valves, etc.	319	tons

Three classes of concrete were used in the dam, of which the following is the specification :—

"*No. 1 Concrete,* for use in the up-stream face blocks, the lining of off-take



View of the Down-stream Face Cataract Dam completed

vertical shafts, and all surfaces exposed to the water, was composed of the following proportions: Cement, 375 lb.; sand, $7\frac{1}{2}$ cub. ft.; bluestone and shivers, 15 cub. ft.; the bluestone and shivers was in proportion of 3 parts of $2\frac{1}{2}$-in. stone to 2 parts of $\frac{3}{4}$-in. shivers."

"*No. 2 Concrete,* for use on the outside of 4-ft. off-take pipes, the lower valve chamber, filling cut-off trenches and tunnels, and the hood of valve chamber on down-stream side, was composed of the following proportions: Cement, 375 lb.; sand, 10 cub. ft.; bluestone and shivers, 20 cub. ft.; the bluestone and shivers being of the same proportions and sizes as for No. 1 concrete."

"*No. 3 Concrete,* for use in the down-stream face of the dam, in the hearting work where voids are large enough, filling shaft, and between the backs of blocks and facing boards, was composed of the following proportions: Cement, 375 lb.; sand, $11\frac{1}{2}$ cub. ft.; and 3-in. bluestone, 20 cub. ft. Approved sandstone metal will be accepted under conditions set forth in Clause 17, in lieu of bluestone."

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"*Special Cement Mortar,* for use in bedding the up-stream blocks, was composed of the following proportions: Cement, 375 lb.; sand, 7½ cub. ft."

"*Cement Mortar,* for use in bedding hearting blocks, and between blocks where the space was too small for No. 3 concrete, and immediately surrounding the 4-ft. off-take pipes, was composed of the following proportions: Cement, 375 lb.; sand, 12½ cub. ft."

Where required, metal work in the form of rails, bars, or other shapes was bedded in the concrete filling between the up-stream or down-stream face-work of the dam, and the hearting blocks of masonry were carried through from the up-stream to the down-stream face of the dam in sections of concrete specially introduced for that purpose between the masonry blocks.

The contractor was permitted, for the convenience of executing the work, to carry up piers within the dam for the support of roads or cranes to such heights as were necessary, provided always that such height, the sectional area in plan, the outline in plan, and the position in the dam of such pier or piers had been approved of by the Engineer.

The lining of the main shafts, inlets from penstocks, and outlets to c.i. pipes from the shafts was of No. 1 concrete, 12 in. and 2 ft. thick, carefully cut and worked on the timber framing, so as to make a sound surface. This work was brought up with the rest of the work so as to ensure its bonding and setting at the same time.

Immediately the framing was removed, the face of the concrete, after any inequalities or defects had been filled with special cement-mortar, was coated with cement wash, as specified, two coats being used where 12 in. thick and one coat where 2 ft. thick.

The sandstone used for the blocks had a weight of 140 lb. per cub. ft., and a crushing strength of 276·3 tons per sq. ft. on a block of 12 in. cube.

Tests of the compressive strength of all concrete and mortar used were made constantly during the progress of the work, and the following are average results:—

IN TONS PER SQUARE FOOT.

	30 days.	60 days.	90 days.
No. 1 Concrete	120·53 tons ...	102·17 ...	116·07
„ 2 „	70·93 „ ...	70·83 ...	—
„ 3 „	61·16 „ ...	96·81 ...	110·77
Mortar	61·42 „ ...	67·68 ...	102·66

The whole of the cement used had to comply with the requirements of the Public Works Department.

The cost of the works is approximately £330,000, made up as follows:—

RESERVOIR AREA.

	£	s.	d.
Clearing	22,908	1	0
Excavation	48,622	5	8
Concrete, etc., in dam, etc.	213,663	1	6
Outlet works	5,393	1	5
Road of access	5,701	6	0
River diversion	4,000	0	0
Valve house	4,849	0	0
Sanitary, medical, and insurance	5,178	10	2
Supervision and contingencies	18,821	6	10
	£329,136	12	7

The plant used on the work cost £33,108, half of which sum only has been included in above statement, the balance being debited to other works on which the plant will be used.

The work of construction was commenced in October, 1902, and the operations carried out included all preparatory work such as road-making, opening out quarries, laying tramways, designing and establishing all plant, excavation for foundations,

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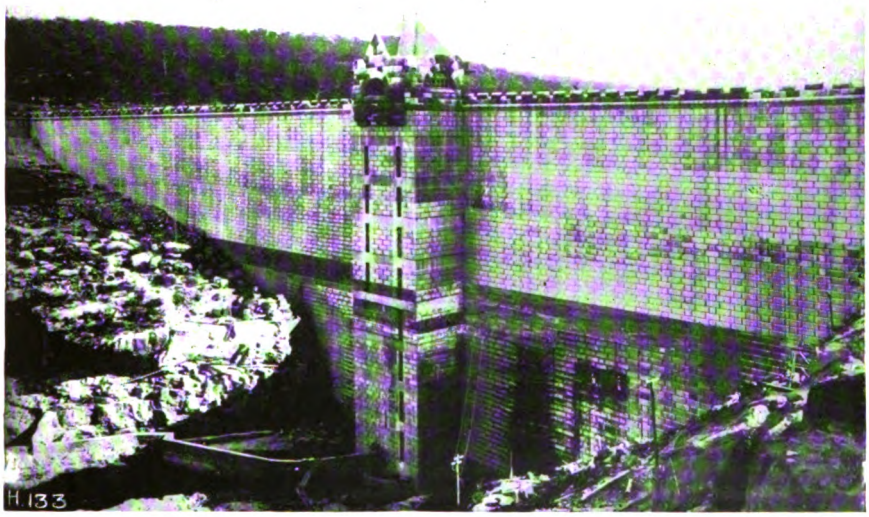
clearing, etc. In addition, a considerable quantity of the hearting and concrete work was built into the foundations. The actual work of building the dam occupied four years and one month, and progressed day and night.

A bywash to pass surplus flood, with a weir 715 ft. long, is provided. The top of the latter is about 150 ft. above the river bed, the overflow water joining the river about ⅛ of a mile below the dam. The top of the dam is 7 ft. higher than the top of the bywash weir. Two 48-in. pipes with valves, communicating with outlet wells and sluice valves in the up-stream face of the work, form the permanent outlet; but two additional 48-in. pipes—making four in all—were provided to pass the river flow during the construction. The valve house on the down-stream side of the dam is roofed with reinforced concrete, to provide against damage by water topping the work during construction; and the contracts provided that the valves should be left open till the lowest portion of the lowest portion reached a level of 80 ft. above the river bed.



View of the Up-stream Face Cataract Dam Completed.

The sandstone used in the construction of the dam was obtained from two quarries, one at each end of the dam, from which the stones were lifted and carried to their destination by cableways. Sandstone suitable for crushing was obtained about half a mile away, and here crushing and sand-washing plants were installed to supply sand. About seven miles up the river hard basaltic stone was quarried to make the concrete, a tramway connecting the quarries with the dam.

For handling stone and concrete six six-ton cranes driven by electric motors and six travelling steam cranes, four of ten tons, one of five tons, and one of three tons capacity, were used. All concrete and mortar were mixed by "Messent" mixers of one cu. yd. capacity each. At the quarry supplying the basaltic stones a "Gates" crusher was erected, producing 40 tons per hour, with a revolving screen separating the metal into different bins according to gauge.

Mr. L. A. B. Wade, M.Inst.C.E., Chief Engineer for Rivers, Water Supply and Drainage, was responsible for the design and carrying out of the structure, and was assisted by Mr. E. M. de Burgh, M.Inst.C.E., of the same department, who had principal charge of the work. Mr. J. Symonds was the resident engineer.

Having regard to the importance of the form of construction here adopted, *i.e.*, the combination of rough masonry and concrete, we present an extract from the specification that should be of some use, especially in our Colonies :—

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EXTRACT FROM THE SPECIFICATION OF THE DAM.

For particulars of the No. 3 concrete and the cement mortar used, see preceding pages.

Hearting of Dam.—The whole of the hearting between the up-stream and down-stream face work to be composed of masonry built of sandstone blocks of as large a size as is practicable, and hewn to a rough rectangular form ; no stone was to be less than 2 ft. in depth, or with a less cubica capacity than 20 ft. when measured on its smallest dimensions. Each stone to be roughly picked to a true surface on the bed, and no stone having a concave bed was to be accepted. The remaining faces of the stone to be roughly spawled off to an approximately rectangular form. The stones to be used green as they came from the quarry, and to be thoroughly washed before laying, with a water-jet not less than ½ in. in diameter, working under a hydrostatic head, or at least 100 ft. The stone to be thoroughly wet immediately before being laid, so that it may not take up moisture from the mortar and concrete with which it comes in contact.

The stones were to be laid so as to form large units of hearting masonry as hereafter described. No horizontal courses would be permitted. The stones were selected of such varying height as to make the horizontal jointing as irregular as possible. Stones were laid upon their natural bed ; but n order to obtain a maximum of irregularity in height this rule could be departed from where directed. The joints in plan were also irregular, and the stones were selected with the special object of avoiding straight joints extending along two or more stones. Each stone was laid upon a full bed of mortar, so that when lowered into position there would be sufficient mortar to allow the stone to sink into it at least 3 in.

Stones were subjected to a series of blows given simultaneously by a number of heavy wooden beaters to the satisfaction of the superintending officer. Any stone which the superintending officer considered may not be bearing over the whole area of its bed upon the mortar had to be lifted and reset to his satisfaction. Vertical joints between adjoining stones, which were large enough, and in such a position as to admit of concrete being thoroughly rammed therein to the satisfaction of the superintending officer, were filled with No. 3 concrete, all other joints being thoroughly filled with cement-mortar. No masonry was laid which, in the opinion of the superintending officer, would disturb or injure the concrete, or jointing, or filling between the masonry below it. In cases where it was necessary to make up a bed, No. 3 concrete was used, or where the contractor thought necessary, built in selected sandstone handstones. Handstones had to be carefully wetted and laid in cement mortar. The use of cement mortar in beds, joints, or filling where No. 3 concrete or sandstone rubble could be used was not allowed, nor was the contractor allowed to use sandstone blocks so roughly hewn as to cause the mortar and the No. 3 concrete used in the hearting masonry to exceed 30 per cent. of the total bulk of such masonry.

The sandstone masonry which composed the hearting of the dam was not carried up in a section of long horizontal layers, but in blocks of varying heights having vertical faces and irregular rectangular outlines in plan. Each block was built of an area no less than 600 ft. in plan, and not less than 15 ft. high, though, when a reduction in these dimensions was deemed advisable, it was conceded to by the engineer; each block varied in height from those adjoining it to an extent of not less than 5 ft. It must be remembered that the position, size, shape, and order of construction of these blocks of hearting masonry were fixed from time to time, as the work proceeded, by the engineer, whose directions in regard thereto were carried out irrespective of the convenience of working plant or any other consideration whatsoever. Upon the completion of such hearting masonry, the spaces between the hearting masonry and the boarding in the down-stream face and the hearting masonry and rock sides of the excavations were filled in with No. 3 concrete, special care being taken to ram it against the boarding in the down-stream face.

This concrete filling for any section was put in in one operation, so that the whole section would set simultaneously. The building of the concrete blocks to form the up-stream face of the dam followed on that of the hearting masonry, and the space between that and the hearting masonry was filled in with No. 3 concrete. Great care was taken that the masonry should not approach the facing blocks or boarding so near as to have prevented the access of men to efficiently ram the concrete between the two, and the space so left was of continually varying widths, and the joining blocks of hearting masonry did not terminate at the same level, but were built of such irregular sizes, shapes, heights, and bulk as secured a thorough breaking of joint between them in every direction, similar to that already described, in the laying of the individual stones of which the masonry is composed.

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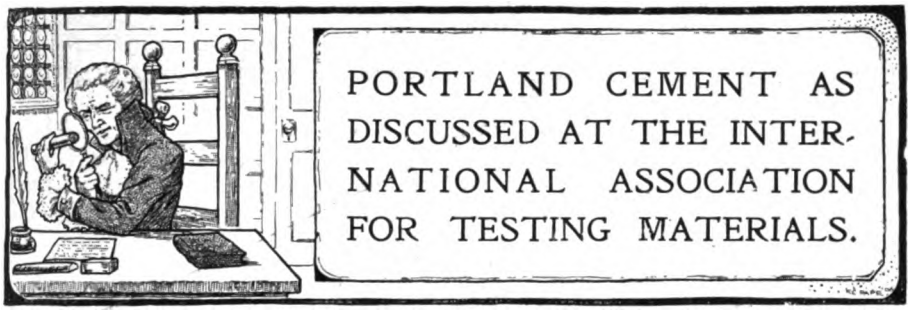

As indicated in our editorial columns various papers and reports on Portland Cement were presented at the recent Copenhagen meeting of the International Association for Testing Materials.

The more important of these papers will be published in this journal, not only as valuable contributions to a much discussed subject, but also as of special utility for reference purposes.—ED.

INTERNATIONAL CONGRESS FOR TESTING MATERIALS.

The following papers were presented on the occasion of the International Congress on Testing Materials at the meeting of Section B, which dealt with concrete, reinforced concrete and Portland cement. Papers dealing with Portland cement were taken on Wednesday, Thursday and Friday, September 8th, 9th and 10th, Captain Grut, of the Danish Royal Engineers, acting as local Chairman and the Hon. Foreign Presidents of the section also being present.

ON ACCELERATED TESTS OF THE CONSTANCY OF VOLUME OF CEMENTS.

A Report presented by BERTRAM BLOUNT, F.I.C. (London).
(*Chairman of the Committee.*)

THE Committee appointed for the solution of Problem 32 "On Accelerated Tests of the Constancy of Volume of Cements," consisted of the following members: —

G. Greil, Baurat im Stadbauamt, Wien (Austria)
Th. Pierus, Ingenieur, Zementwerks-Direktor, Wien (Austria).
E. Hiertz, chef de service de la Société Cockerill, Seraing (Belgium).
M. Petersen, Ingenieur der Dänischen Staatsprüfungsanstalt, Kopenhagen (Denmark).
Bertram Blount, Chemical Laboratory and Testing Works, London (Great Britain).
R. Curling Styles, Chemist to the Associated Portland Cement Manufacturers (1900), Ltd., London (Great Britain).
E. Leduc, chef de section au Lab. du Conservatoire des Arts et Métiers, Paris (France).
F. M. Meyer, Fabriksdirektor in Malstatt (Germany).
F. Schott, Direktor der Portlandzementfabrik, Heidelberg (Germany).
L. Bienfait, Ingenieur, Mitinhaber der Materialprüfungsanstalt, Amsterdam (Holland).
D. von Nagy, Professor am kgl. Polytechnicum, Budapest (Hungary).
J. Zhuk, Ingenieur der Versuchsstation, Budapest (Hungary).
O. Rebuffat, Dr., Professeur et Directeur du Cabinet du Chimie à l'Ecole royale supérieure Polytechnique (Italy).
O. Carlsen, Direktor der technischen Schule, Bergen (Norway).
A. Baykoff, Professeur de la Polytechnique, St. Pétersbourg (Russia).
O. Blaese, Chemiker, Zementfabrik, Port Kunda (Russia).
E. Schwarz, Chimiste, Fabrique de Cements Noworossiisk (Russia).
V. Tagucet, Ingénieur au Lab. méc. à l'Inst. des voies de comm., St. Pétersbourg (Russia).
R. W. Lesley, President American Cement Co., Philadelphia (United States).
S. R. Newberry, Manager Sandusky Portland Cement Co., Sandusky, Ohio (United States).

A meeting of the Committee was held at Brussels on January 26th, 1903, which was attended by the members mentioned as follows:—Bertram Blount (Chairman), E. Hiertz, Mayntz Petersen, R. Curling Styles, E. Leduc, L. Bienfait.

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At this meeting it was decided that some form of hot test should be adopted as a standard accelerated test for the constancy of volume of cement. Experiments were to be made on samples procured from the various countries represented to decide the best temperature for the test and the most suitable means of measuring the expansion of the test pieces.

A representative of each country was chosen to carry out the experiments; the following is a list of the members invited to undertake this work:—Alfred Greil (Austria), Mayntz Petersen (Denmark), R. Curling Styles (Great Britain), E. Leduc (France), F. Schott (Germany), L. Bienfait (Holland), Des. Nagy (Hungary), O. Carlsen (Norway), E. Schwarz (Russia), R. W. Lesley (United States).

A detailed programme of the methods of carrying out the tests was given in Appendix I. to the Brussels Congress report.

A report of the resolutions formulated by the meeting at Brussels was communicated to each member of the Committee, and a copy of the programme of work with an invitation to co-operate was sent to the members chosen by the Committee to carry out the experiments.

Requests were sent to members of the Committee and others for samples of cement on which to experiment. The samples were to be (1) sound, (2) doubtful, and (3) unsound. It was arranged that portions of each sample should be distributed to those members of the Committee who were willing to undertake the work of experimenting.

A letter was addressed to M. Rebuffat asking him to investigate the nature of the substances which tend to cause the expansion of cement with the view of arriving at a means of identifying and determining them by proximate analysis or microscopically.

Working on the lines laid down in this programme Mr. Leduc (France), Mr. Bienfait (Holland), Mr. Schwarz (Russia), Mr. Petersen (Denmark), and Mr. Styles (England) have carried out a series of tests according to the programme and have communicated the results of their experiments. These results are given in Appendix II. of the above-mentioned Brussels Congress Report.

On examining the results given in these tables it is evident that the ordinary cold water pat test at 28 days is not capable of detecting with certainty a cement known to be unsound, and that it fails completely to detect a cement of doubtful soundness.

It is also apparent that there is much difficulty in obtaining concordant results with the Bauschinger apparatus used by different operators. Apart from possible errors of manipulation this difficulty may well be caused by slight movement of the small metal plates inserted at each end of the test piece, between which the measurement is made. If the cement is expansive a displacement of these plates is rendered more probable and the difficulty of obtaining concordant results will be increased.*

The Le Chatelier test, on the other hand, gives results which are fairly concordant for different operators. Such divergencies as exist may reasonably be attributed to the fact that the samples were not all tested at the same time, and however carefully they were packed and stored may have become slightly aerated in some cases and thus made less expansive. It is also clear that tests at 15° C. and at 50° C. do not suffice to detect a doubtful or unsound cement with certainty, but that when the test is carried out at 100° C. as originally prescribed by Le Chatelier it is easy to detect even a doubtful cement, whereas a sound cement withstands the test perfectly, expanding to the extent of only a few millimetres.

The behaviour of the three samples specifically referred to in the Brussels Congress

* The metal plates should be set in with cement known to be absolutely sound, not necessarily with the cement to be tested.

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Report is typical of that of the various other samples examined by different members of the Committee. In all, five sound samples, five doubtful samples, and four unsound samples were submitted to tests for constancy of volume. Without exception the cold pat test at 28 days was inadequate to detect with certainty doubtful samples or even samples known to be unsound. The tests at 50° C. sufficed to detect samples thoroughly unsound, but could not be relied on to detect doubtful samples. The only perfectly reliable tests were those at 100° C.

Since the Conference in Brussels and the report dated December 24th, 1903, no work has been officially undertaken by the Committee in its corporate capacity. Mr. Schwarz has, however, been good enough to communicate results obtained by tests continued over a long period by the Bauschinger apparatus. They constitute a useful addition to the work already reported which relates to shorter periods.* His comments are made as an individual member of the Committee.

The question of the constancy of volume of cements has now been advanced to a point where a definitive conclusion can be stated. The experiments carried out under the auspices of Committee No. 32 showed that an accelerated test at a high temperature could be fulfilled without difficulty by modern cements carefully manufactured and of high quality. It also showed that cements of doubtful quality were not easily distinguished from those which were free from all defect except by a high temperature test. All cold water tests and hot tests which were simply qualitative were found to be inadequate. Nothing which has occurred since the date of the Committee's report has tended to invalidate this conclusion, but a good deal has happened to confirm it. The accelerated hot test, at first strenuously resisted by manufacturers, has been accepted unreservedly in England. The British Standard Specification now requires that the expansion of a Le Chatelier test piece shall not be greater than 10 mm. after the cement has been aerated for 24 hours, and 5 mm. after the cement has been aerated for 7 days. This test is complied with habitually, and many cements are so free from expansion that these maximum limits are regarded by many as unduly high. During the early stages of the enquiry which preceded the conclusion of the British Standard Committee some doubt was expressed as to whether the Le Chatelier apparatus was suitable for comparatively rough use, such as that to which it would be subjected at a cement works or by the ordinary engineering staff on a large constructional undertaking. Experience has shown that no such difficulty occurs. As a natural result the Le Chatelier test is established in England as the standard method with which makers, users and engineers are satisfied.

CONCLUSIONS.

In view of these facts it appears desirable that the Le Chatelier method for determining constancy of volume of cement should be adopted by the International Society as its standard method, and the following proposal is laid before the Congress :—

> "That the Congress decides to recommend the method of Le Chatelier as the standard accelerated test for the constancy of volume of cements. The method is to be carried out as follows :—
>
> "The cement is gauged and filled into the mould on a plate of glass, the edges of the mould being held together. When the mould has been filled it is covered with a plate of glass held down by a small weight, and the whole is immersed in water at 15° C. for 24 hours. Any tie or band which has been used to keep the edges of the mould together during setting is then removed. The distance between the indicator needles is measured and the mould is placed in cold water which is raised to a temperature of 100° C. in the course of half an hour and is kept boiling for 6 hours. The mould is removed from the water, and after it has cooled the distance between the indicator needles is again measured. The difference

* A copy of Mr. Schwarz's figures is appended to Mr. Blount's report.

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between the two measurements represents the expansion of the cement. This must not exceed 10 millimetres when the cement has been aerated for 24 hours, and 5 millimetres when the cement has been aerated for 7 days."

RAPID METHODS FOR DETERMINING THE STRENGTH OF HYDRAULIC CEMENTS.

Committee-Report presented by Dr. Fr. BERGER, Vienna.

TOGETHER WITH APPENDICES BY MR. L. DEVAL, OF PARIS, AND MR. ALF. GREIL, OF VIENNA, RESPECTIVELY.

(Translated from the German original by A. R. Liddell, Charlottenburg.)

After the death of Prof. L. von Tetmajer, of Vienna, and Prof. A. Cossa, of Turin, M. F. Behrmann, of Riga, and the retirement of Mr. D. Wassenko and Mr. S. Drouginine, of St. Petersburg, the Committee comprised the following members :—

Chairman: *Dr. F. Berger*, K.K. Sektionschef, Stadtbaudirektor a.D., Vienna.

MEMBERS.

E. Camerman, Chef du Service des essais des chemins de fer de l'Etat Belge, Brussels.

D. Berg, Director, Portland Cement Works, Aalborg (Denmark).

C. Heinitzel, Dr., Chemist, Laboratorium für Zementindustrie, Lüneburg (Germany).

W. Michaelis, sen., Dr., Cement Expert, Berlin (Germany).

F. Schott, Director, Portland Cement Works, Heidelberg (Germany).

J. A. Ewing, Prof., F.R.S. Engineering Laboratory Cambridge (England).

E. Candlot, Portland Cement Maker, Paris (France).

A. Mesnager, professeur à l'Ecole des ponts et chaussées, ingénieur en chef des ponts et chaussées, Paris.

R. Feret, chef du Laboratoire des ponts et chaussées, Boulogne-sur-Mer (France).

L. Bienfait, Ingenieur, Testing Establishment for Building Materials, Amsterdam (Holland).

Morris, Dr., Chief Chemist to the "Christiania Portland-Cementfabrik," Christiania (Norway).

A. Greil, Baurat, Vorstand der städtischen Materialprüfungsstation, Vienna (Austria).

D. Nagy, v., Professor of the königl. ungar. technischen Hochschule, Buda-Pesth (Hungary).

N. Belelubsky, Dr., Exc., Professor at the Imperial Russian Road Engineering Institution, St. Petersburg (Russia).

N. Bogdanoff, C.E., St. Petersburg (Russia).

T. Schilling, Chief Chemist to the Moscow Cement Co., Podolsk (Russia).

L. Proskuriakoff, professeur de laboratoire de l'école des ingénieurs, Moscou (Russia).

A. Wikander, Professor, Göteborg (Sweden).

W. W. Maclay, C.E., Detroit, Mich. (U.S.A.).

Ch. F. McKenna, Chemist, New York (U.S.A.).

On the basis of the experiments made in the Federal Testing Laboratory in Zurich, and in the Municipal Testing Laboratory in Vienna, the Chairman of the Committee laid before the Buda-Pesth (3rd) Congress of 1901 a report which concluded with the following proposal :—

"As a preliminary indication of the strength development of Portland cement in tension and compression the six-day hot-water test can be used.

"The briquettes composed of 1 part Portland cement by weight and 3 parts standard sand should be kept in a damp closet for 24 hours after moulding, protected from currents of air and sunlight. The hot-water bath, after the introduction of the briquette, should be gradually heated from 15 deg. C. to 100 deg. C. within two hours, and be kept at this temperature. The water should be changed after three days and replaced by water of the same temperature.

"The employment of hot-water tests for the preliminary testing of the strength of Portland cement is not intended to dispense with the standard cold-water test."

The 3rd Congress has taken cognisance of this proposal, and has invited the Committee to continue their work in accordance therewith.

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In October, 1901, the Chairman after the Buda-Pesth Congress distributed a fourth circular among the members of the Committee. In this circular the members were desired to continue their studies on this question, and to give their views on the proposal above cited.

The circular further contained a reproduction of a communication subsequently handed in by Messrs. Belelubsky, Bogdanoff, Wassenko, and Konossewitsch in support of the hot-water test, and an intimation that the test-results given in the reports of the Buda-Pesth Congress bore reference only to hydraulic cements of constant volume and that the accelerated 6-day hot-water test for obtaining provisional information, referred to in the above proposal, had, in August, 1901, been included in the Swiss Cement Standards.

Seeing that no expressions of opinion relating to this circular were sent in, and that the Council had, at their meeting of February, 1907, decided that Committee No. 9 should be proceeded with, the Chairman in a fifth circular, dated April 1st, 1907, again invited the members of the Committee to send him their proposals in regard to the question in such time that a report could be drawn up and presented to the Congress in Copenhagen in 1909.

In answer to these invitations, the following communications were sent in :—

Mr. B. Feret, Chief of the Laboratory in Boulogne-sur-Mer, wrote on April 25th, 1907 :

"In answer to your fifth circular, relating to the question of Committee No. 9, I beg to remind you that the observations made by several investigators tend to show that there is no proportionality between the degrees of strength attained by the test samples after they have laid for several days in hot water and after they have been kept for long periods in cold water respectively.

"I think it probable, therefore, that the accelerated test will not be able to yield results of any sufficient degree of interest."

Mr. L. Bienfait, Co-Chief of the Material-Testing Institution in Amsterdam, wrote on May 3rd, 1907 :

"Although up till the time of the Buda-Pesth Conference an accelerated strength testing process consisting in the keeping of the test samples in hot water could perhaps be recommended, this seems, in view of the present conditions of the manufacture of cement, to be superfluous. After 6 days' hardening in water of 15° to 18° C., indeed, by far the greater number of the Portland cements show such degrees of strength that a 6-day test of this kind may easily be made and regarded as final. Moreover, tests of only 6 days' duration are often specified for Portland cement. If a searching test of an unfamiliar Portland cement be desired, the 6-day test will not be sufficient, and its extension so as to embrace a period of 1, 3, 6, or 12 months may be desirable. The troublesome and somewhat expensive hot-water test, in connection with which the samples have to be kept for 6 by 24 hours day and night in water of 100°, is, in my opinion, a process to which we should not go over."

Dr. W. Michaelis, Cement Technicist of Berlin, writes on April 22nd, 1908, as follows :

"I have always proposed and strongly recommended this accelerated hot water test, after having long ago established the fact that in this way—not without exception, it is true—such an acceleration of the development of strength took place in the hydraulic hardening process that the samples hardened in 7 days with the water at 100° C. were about equivalent to those hardened in 28 days with the water at 15° to 18° C.

"Now, since condemnations occasionally take place, the attainment of complete unanimity in regard to this accelerated process will probably not prove possible. I myself, however, give my vote for this test ; for why shall we, on account of exceptions such as are everywhere encountered, refuse to help such a useful rule to recognition ? "

In April, 1908, Mr. L. Deval, formerly Director of the Municipal Testing Establishment of Paris, submitted a detailed report supported by numerous results of experiments, which appears in the form of a separate contribution to the report of the Committee, and in which the following results are reached :

"The strength of the hydraulic cements increases step by step in hot water for at least a year.

"On the other hand, the strength, although less in the beginning, increases more rapidly than in the other case, and continues to increase for a few months longer still.

"In regard to the value of the hot-water process as a rapid test, it cannot be admitted without risk of error, that this hot-water test yields the same result after 7 days as does the cold-water test after 28 days.

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"The hot water-test does not, after 7 days, give clear indication as to what the ultimate strength of the cement will be. It gives information neither as to the maximum strength attainable in cold water, nor as to the strength value after a test of three years—the period of test here ruling.

"Cements, in connection with which the hot-water rapid test has not shown a favourable result, or which are puffed up by the hot-water, are not necessarily useless—at any rate not during a period of 3 years. The strength of such cements increases in cold water in like manner to that of the ones which show a favourable result under the hot-water test, and it may prove nearly the same as that of the latter.

"The hot-water test, nevertheless, has a tangible advantage; for it enables the presence of materials (which expand or shrink) to be detected.

"In our experiments the cubes were not acted upon by any external force. They were able to gradually attain a degree of strength which enabled them, without perceptible alteration of form, to withstand the internal strains set up—during a period of at least 3 years—by the slow hydration of the expansive substances. The assertion is not justified, however, that the same thing happens during a long period of immersion, or under other less favourable circumstances, as, for instance, in sea water or under the influence of the atmosphere.

"To sum up, we may say that although it does not appear possible from the strength point of view to found upon the hot-water test a method for the rapid testing of cements, the hot-water treatment, nevertheless, yields valuable information in enabling the presence of expansive ingredients to be detected."

In June, 1908, Baurat A. Greil, Manager of the Municipal Testing Establishment for Hydraulic Cements in Vienna, sent in a report, which was supported by results of experiment, and which is likewise printed as a separate contribution towards the work of the Committee. Mr. Greil comes to the conclusion that on account of the unreliability of this method of testing, its adoption is not to be recommended.

CONCLUSIONS.

Of the five gentlemen whose opinions are given, Dr. Michaelis is in favour of the hot-water test, while Messrs. Feret, Bienfait, Deval, and Greil are unable to recommend it.

The following are the conclusions arrived at:—

The numerous test-results given are in fact so contradictory that the hot-water test appears too unreliable to admit of its being employed for rapid tests made to determine the strength of hydraulic cements.

In the circumstances, then, it appears the right course not to pursue the question of the applicability of the hot-water process for the acceleration of the testing of the strength of hydraulic cements any further.

On the other hand, the experiments of Mr. Deval have once more demonstrated how valuable this test may be for the giving of information as to the tendency of the cements to swell up and crack.

The question as to the attainment of constancy of volume of the cements is under consideration by Committee No. 32, which will no doubt take these suggestions into account.

Now while the proposal is made, that the question of the hot-water test as a rapid method for determining the strength of cements be allowed to drop, this does not mean that Committee No. 9, which was appointed to consider it, shall be dissolved, but rather the suggestion is put before the individual members that they pursue this important subject further, and it is thought that an elucidation of the chemical processes at work in the material may yield tangible results such as may be applied so as to admit of a more rapid judgment of cements.

Any results of experience that may be obtained should then be communicated to the Chairman.

At the end of March, 1909, the foregoing report was sent to all the members of the Committee in a sixth circular in which these gentlemen were desired to give expression to their views with regard to it by the end of April.

Answers favourable in every respect were received from the following gentlemen:—Mr. L. Bienfait, of Amsterdam, Mr. R. Feret, of Boulogne-sur-Mer, Mr. A. Greil, of

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Vienna, Dr. C. Heintzel, of Lünneburg, Mr. W. W. Maclay, of Detroit, Michigan, and Prof. D. P. Nagy, of Buda-Pesth.

Dr. W. Michaelis, of Berlin, attributes the discrepancies (condemnations) in connection with the hot-water test to the insufficient homogeneity of the original mixture, but admits that when rational advantage is taken of the improvement of the cements effected by means of finer grinding, a good idea of their performances may already be obtained in a much shorter time than formerly.

In view of this result of Circular No. 6, the Chairman believes himself justified in laying the above conclusions, as the expressed opinions of the Committee, before the 5th Congress for final decision.

NOTE ON THE RAPID TESTING OF CEMENTS TREATED WITH HOT WATER.

By M. E. DEVAL, Paris.

APPENDIX TO THE REPORT OF COMMITTEE 9.

(Translated from the French by A. R. Liddell, Charlottenburg.)

Generally.—When the hydraulic cements contain neither expansive ingredients (lime and magnesia in excess) nor salts that are decomposable by boiling water, hot water (at a temperature of 100° C.) gives their mortars at the beginning of their immersion greater strength than cold water.

On the other hand, hot water produces a rapid hydration of the expansive ingredients, which shows itself, either in a diminution of the strength, or in swellings and cracks.

According to the circumstances, then, hot water may accelerate or retard the hardening of the mortar.

We have endeavoured, at different stages in the hardening process, to compare the strengths of the hydraulic cements (neat and sand briquettes) immersed in hot water (of 80° to 100° C.), with those attained by the same materials after the same times of immersion in cold water (of 15° to 18° C.).

We have then investigated the question, whether hot water, which at the outset gives greater strength to the mortars, could be used for the rapid testing of cements, and would give any indication of their ultimate strengths.

Briquettes.—Our briquettes in figure-of-8 form have a sectional area of 5 sq. cm. The neat briquettes were prepared with 25 per cent. of water, and the sand briquettes with a proportion of water equal to 11 per cent. of the combined weight of cement and sand. These latter mortars had the consistency of moist earth and were stamped into the moulds.

The briquettes were kept sheltered from draughts and from the rays of the sun for 24 hours in the laboratory cellars before being immersed either in hot or in cold water.

The strength increases with the time of immersion in hot water.

Tests.—Our tests were made on Portland cement, slag cement, and quickly setting Vassy cement.

The briquettes were broken by tensile strain after periods of 2 days, 7 days, 28 days, 3 months, 6 months, 9 months, and one year respectively.

In connection with the Portland cements, we have found that the strength of the neat briquettes under the heat treatment, which is at first greater than that under the cold one, gradually rises in spite of some irregularities in the results, but increases less rapidly than the strength in cold water, which almost always exceeds the other at the end of a year. The strength of the sand briquettes (1 part cement to 3 parts by weight of standard sand) in hot water keeps its place, except in a few cases, above that in cold water at all stages of the tensile tests.

Aluminous Cements.—With very aluminous cements, such as those made of slag, which contain from 15 to 16 per cent. of alumina, and therefore a large proportion of aluminate of lime, the general course of the hardening process is the same. It not infrequently happens, however, that the strength of the neat briquettes in hot water

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at the end of two or even of seven days remains less than that in cold water by reason of the dehydration of the aluminate of lime by the water of 100° C. The strength of the sand briquettes under heat is in general superior to that under cold at all stages of the tensile tests.

In regard to the quickly-setting cements, such as the Vassy cements, the neat briquettes are found to give results similar to those with Portland cements; but with the sand briquettes (2 parts by weight of cement to 5 of sand) the similarity is less complete.

In short, the strengths of the Portland, slag, and Vassy cements (whether in the forms of neat or sand briquettes) continues to increase in hot water for a year, which was the limit of duration of our tests.

Hot-Water Tests. — In view of the circumstances that hot water in general accelerates the setting of mortars and increases their strengths, at least at the beginning of their immersion, the attempt has been made to found a method of rapid testing of cements on the hot-water process. Some experimenters have thought that the strength in hot water after a 7-days' immersion would be sensibly the same as that in cold water after a 28-days' immersion. Our experiments relating to this point have only been extended to neat briquettes of Portland cement.

Amongst 109 tests, we only found 14 the results of which differed from one another by less than 3 per cent. of the strength-value under heat and 33 in which the difference did not exceed 19 per cent. The differences are sometimes positive and sometimes negative; they range up to 63 per cent.

Results. — It will be apparent, then, that, even though a variation of 10 per cent. were regarded as negligible, an agreement of results is established only for 47 tests out of 109. The experimenter, then, may be said to run the risk of deluding himself in 57 cases out of 100, should he take, as the probable strength of cement in cold water after a 28 days' immersion, that which he would have found by a rapid test in hot water.

Tensile Tests. — Can the tensile tests on neat briquettes after 2 and 7 days' immersion in hot water respectively, nevertheless give indication of the ultimate strengths of these cements and of their mortars? We do not think so; for we have not found any proportionality between the strengths of the cements in hot water after seven days and those which they develop in cold water at any period of their immersion ranging up to three years.

We cannot here set forth all the results of our numerous tests; we shall only give some of them in the following table in order to show that equal strengths obtained under 7-day heat tests may correspond with strengths under 3-year cold water tests that differ widely from one another and *vice versâ*. It may indeed be observed that the strength after 3 years may even be less than that in the 7-day test with hot water.

	In Kilogrammes													
Strengths in hot water after 7 days' immersion ...	53·60	50·70	42·50	22·00	40·00	34·25	42·75	39·00	29·50	38·00	53·75	44·00	54·75	51·50
Maximum strengths after from 2 to 3 days in cold water	66·75	71·00	65·25	58·75	58·25	50·00	50·50	53·50	56·00	61·65	67·25	68·00	63·25	58·70
Strengths in cold water after 3 years' immersion ...	54·50	58·50	65·25	58·75	58·25	50·00	41·25	35·75	54·00	57·25	60·25	61·75	59·25	55·25

Should we *à priori* reject the cements for which the rapid test under heat has shown the presence of expansive ingredients?

Cold Water Tests. — We have observed above that the cements that are devoid of expansive ingredients, will, when first immersed, show greater strengths in hot than in cold water. Such is the behaviour of cements reputed to be of good quality. Cold water tests which we have made on cements of this kind, immersed for periods of three years, have shown us that the curve of results given by breaking at different periods varying from two days to three years, shows ups and downs and a maximum which

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does not necessarily correspond with the result of the last test. This maximum, which shows itself at different periods, according to the cement in question, does not occur simultaneously in the tests on the neat briquettes and on those of the corresponding sand briquettes.

The cements which in hot water show departures from the general rule which we have just enunciated in our experiments, behaved in three different ways :—

1. The strength in hot water has been less than that in cold water, it may be after two days or after seven days.
2. A fall is shown in the strength under the hot test on the seventh day.
3. The hot water has developed cracks and swellings.

These anomalies are attributed to the hydration of the expansive ingredients; the uncombined lime and magnesia, which have been overburnt during the manufacture of the cement, are then hydrated only very slowly, while hot water facilitates their hydration. This may begin at the beginning of the experiment, as in the first case, or it may not show itself till after an immersion of several days, as in the second case.

Lengthy Cold Water Tests.—Side by side with the rapid tests with hot water, we have with the same cements undertaken tests of long duration in cold water in order to ascertain whether the cements, showing the anomalies to which we have just referred, show certain irregularities in the cold-water test of such a kind as to cause them to be looked upon as defective. We have found, on the contrary, that the setting and hardening in cold water are not influenced in the same way as in the case of the cements which in hot water follow the ordinary rule. The curve of strength shows ups and downs, and passes through a maximum which is not always at the point corresponding with the last test.

Tests.—The following table gives the limits between which, according to our experience, the maximum strengths and the strength after three years of immersion have varied for the cements which have followed the general rule and for those which have shown the different anomalies referred to above.

Results of the Hot Tests with 2 and 7 days' Immersions	Strength maxima in Cold Water. kgs.	Strength After 3 Years' Immersion in Cold Water	
		Pure Cakes kgs.	Mortar ½ kgs.
The strength at the hot test is superior to that at the cold test	from 40·25 to 71·00	from 32 25 to 68·25	from 16·50 to 40·25
The strength at the hot test is inferior to that at the cold test	„ 52·50 „ 68·25	„ 42·25 „ 57·25	„ 20·00 „ 43·25
A fall occurs in the strength at the hot test on the seventh day	„ 45·00 „ 62·50	„ 39·00 „ 62·50	„ 19·75 „ 40·50
The hot water has caused swellings or cracks	„ 45·25 „ 58·00	„ 40·50 „ 58·00	„ 22·75 „ 35·00

The cements of the first line are those which are reputed to be of good quality. It will be observed, that the cements of the 2nd, 3rd and 4th lines, which have shown anomalies in hot water, have in cold water acquired strengths that fall within the limits shown by those of good quality.

From the point of view of the strength to which they can attain, whether in the form of neat or sand briquettes, the cements whose briquettes develop swellings in hot water are not, therefore, necessarily bad. The hot water has merely enabled us to recognise the presence of an element which, though perhaps a source of future danger, does not show itself during the three years that our experiments lasted. It is, further, a matter of common knowledge that a short exposure of a cement to moist air often suffices to prevent it from swelling further in hot water.

CONCLUSIONS.

The conclusions which the experiments, the results of which we have briefly touched upon in the foregoing, have led us to form may be formulated as follows :—

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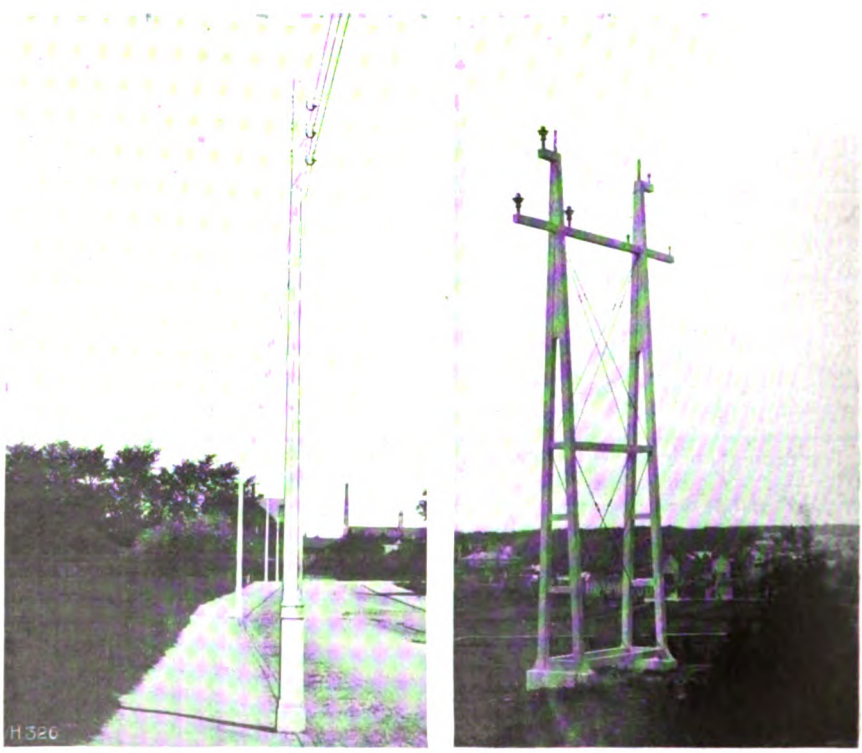
(*a*) The strength of hydraulic cements increases progressively in hot water for at least a year; but the strength in cold water, at first inferior to the first-mentioned, increases more rapidly and takes the lead after a few months.

(*b*) From the point of view of rapid testing it cannot be said that strength under the hot test at the end of 7 days is always equal to that in cold water at the end of 28 days.

(*c*) The hot-water test does not, after a 7 days' immersion, enable the ultimate strength of the cement to be predicted. It gives no certain information, either as to the maximum attainable by the strength under the cold treament, or as to the value that the latter will show at the end of the three years to which our tests extend.

(*d*) The cements for which the rapid hot test has been unfavourable, or which hot water has caused to swell, are not necessarily dangerous, at any rate for a period of three years. Their strength increases in cold water in a manner analogous to that of the cements the hot tests of which have been satisfactory, and this strength may become nearly equal to that of the latter. In our experimenting troughs, however, where the briquettes have been submitted to no external strain, they have been able gradually to acquire sufficient strength to withstand the internal strains set up by the slow hydration of the expansive ingredients without visible deformation. It cannot, however, be asserted that the same will be the case for a longer period of immersion than three years, or under other less favourable conditions, as, for instance, near the sea or under the influence of atmospheric agents.

To sum up, we may say, that although it does not appear possible from the strength point of view to found upon the hot water test a method for the rapid testing of cements, the hot-water treatment nevertheless yields valuable information in enabling the presence of expansive ingredients to be detected.



REINFORCED CONCRETE TELEGRAPH AND ELECTRIC TRAMWAY POLES.

(*See "New Uses."*)

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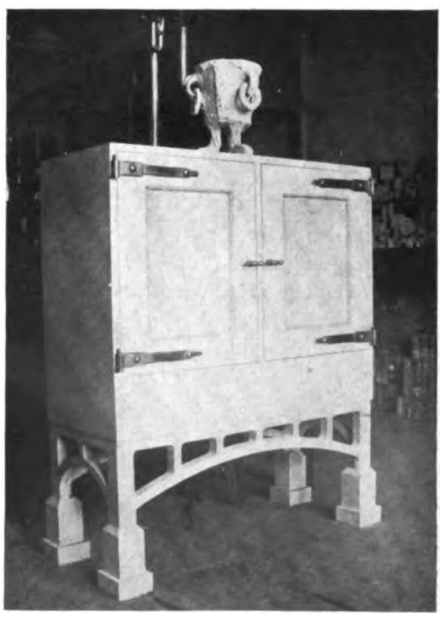
NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

EXAMPLES OF REINFORCED CONCRETE FURNITURE.

EXTENSIVE harbour improvements are in progress at Aberdeen Harbour for the accommodation of the large fishing fleet which operates from this port and, amongst other works, includes about one mile of wharves in reinforced concrete, designed on the Considère System. A very complete chemical and physical laboratory is attached to the engineer's department, in which many interesting examples of reinforced concrete work are to be seen.



REINFORCED CONCRETE CABINET.

The accompanying photographs show two of these, one being a neat table for office use, and the other a moist cabinet for the storage of cement briquettes before testing for tensile strength. Cabinets of a similar nature have been made at other places, but none so complete in every detail. Inside the cabinet are reinforced trays containing the briquettes immersed in water, so that these can be drawn out and the water changed conveniently when required, without disturbing others.

The cabinet is composed of Portland cement and granite sand (graduated) and is reinforced with expanded metal. The cabinet itself is moulded in one piece, with top

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and side walls 1 in. thick and bottom $1\frac{1}{4}$ in. thick; the doors were moulded separately and are 1 in. thick, the panels being $\frac{1}{2}$ in. thick. The door fittings are moulded into the walls of the cabinet, as seen in the photograph. The under part of the cabinet containing water is fitted with a drain tap. The upper part is fitted with five movable reinforced concrete trays, $\frac{1}{2}$ in. thick, which are perfectly watertight. Number plates are attached to each tray. The under part of one side is fitted with three movable reinforced concrete gratings, $\frac{1}{2}$ in. thick; these gratings are self-moistening from the under part of the cabinet, and provide a damp atmosphere for the briquettes. The stool underneath is also reinforced concrete, moulded in one piece, as is also the flower vase on the top of the cabinet.

The table is composed of Portland cement, and is reinforced with $\frac{1}{4}$-in. steel rods and expanded metal, fastened together with wire, as seen in the photograph. While filling in the concrete the mould was shaken to remove the air bubbles, and by this means a highly finished surface was obtained.

We are indebted to Mr. A. G. Souter, of the Laboratory and Testing Department, Provost Matthew's Quay, Aberdeen, for the illustrations and text.

REINFORCED CONCRETE TABLE.

CONCRETE FOR USE IN DOG KENNELS.

THERE seems to be no limit to the uses to which concrete may now be put, and it is an undoubted fact that reinforced concrete partitions in permanent kennels will be found extremely strong, and above all cleanly. These partitions may be easily formed by stretching thin split, or perforated iron sheets between uprights, and facing each side with cement. The result is a smooth wall of cement about one or two inches thick.

Concrete is also an excellent material for forming the floor of kennels, owing to the ease with which it can be kept dry and clean, and it is obviously more healthy than boarding.

Special care should be taken to obtain a thoroughly smooth surface and to round off all internal angles.

REINFORCED CONCRETE TABLE.

(View showing reinforcement.)

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REINFORCED CONCRETE TELEGRAPH POLES.

We have previously referred to the telegraph poles of reinforced concrete of Swiss origin, which are to be shortly made in this country.

We have now before us particulars of reinforced concrete telegraph poles constructed by the Danish Concrete Beam Co., of Copenhagen, under the supervision of Captain Moehl, of the Danish Royal Engineers.

It appears that the poles in question, of which some 2,000 have been recently erected, are finding favour in Scandinavia and we hear of a further 500 being on order for Copenhagen.

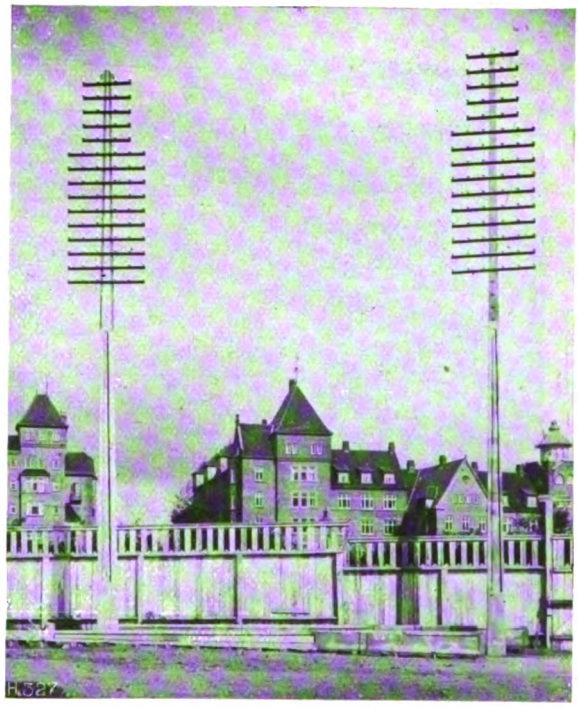
The specimens seen appear to be highly serviceable, and they have the further advantage of looking well.

We understand that some specimen poles of this type have recently been made for the London General Post Office to test, and we are glad to see that the matter is being looked into by that department.

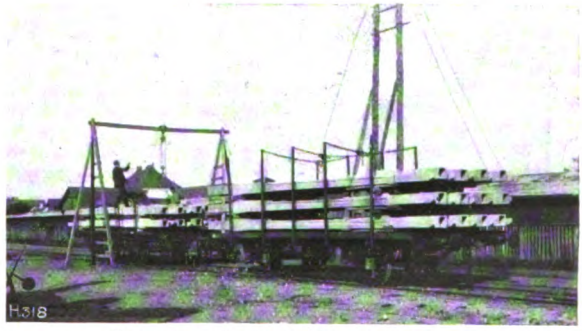
Besides using reinforced concrete for ordinary telegraph poles, reinforced concrete electrical transmission standards are also being made by the same firm.

There is no doubt that reinforced concrete lends itself extremely well to work of this kind, and we observe with interest that there will shortly be two or three types of poles and standards on the market. Now that Germany, Denmark, Switzerland and the United States have taken up the application of reinforced concrete in this direction we feel sure Great Britain and its Colonies will follow suit.

The views we give show different types of poles as applied to various purposes (see also page 356), and we also show a photograph of a batch of these poles loaded up on a railway truck ready for transit.



Reinforced Concrete Telegraph Poles.



Reinforced Concrete Telegraph Poles.
(Awaiting shipment.)

Under "Memoranda," it will be observed that tenders for poles are being invited by the Australian postal authorities, which seems to indicate that our Colonial friends are fully alive to the advantages of reinforced concrete.

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REBUILDING THE CHICAGO UNION STOCKYARDS IN CONCRETE.

DURING the last year extensive reinforced concrete work has been executed at the yards of the Union Stock Yards and Transit Co., of Chicago; the work accomplished so far is the first step in the general plan to substitute reinforced concrete construction for wood throughout the yards. The character of the work and the conditions surrounding it are so different from ordinary reinforced work that a short description of it is of interest. Mr. Holmberg was the designer.

FIG. 1.

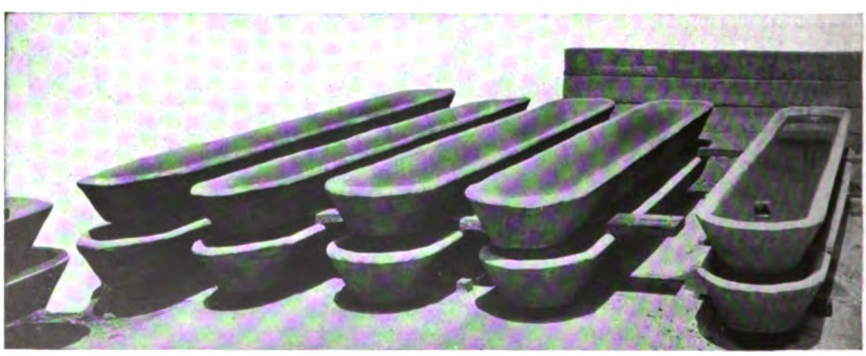

FIG. 2. REINFORCED CONCRETE AT THE CHICAGO UNION STOCKYARDS.

Fig. 1 shows the style of fence that has been adopted for general use throughout the yards. The fence is built up according to a system of piece construction designed by Pierre Holmberg, engineer-in-charge. The posts, fence rails and caps, are cast in multiple forms, each form taking from three to nine pieces at the same time, the average slab thickness being $1\frac{3}{4}$ in.

Fig. 2 shows a number of watering troughs used in the pens for watering the stock. These troughs are 16 ft. long, about $7\frac{1}{2}$ in. deep, and the average thickness is $3\frac{3}{4}$ in.

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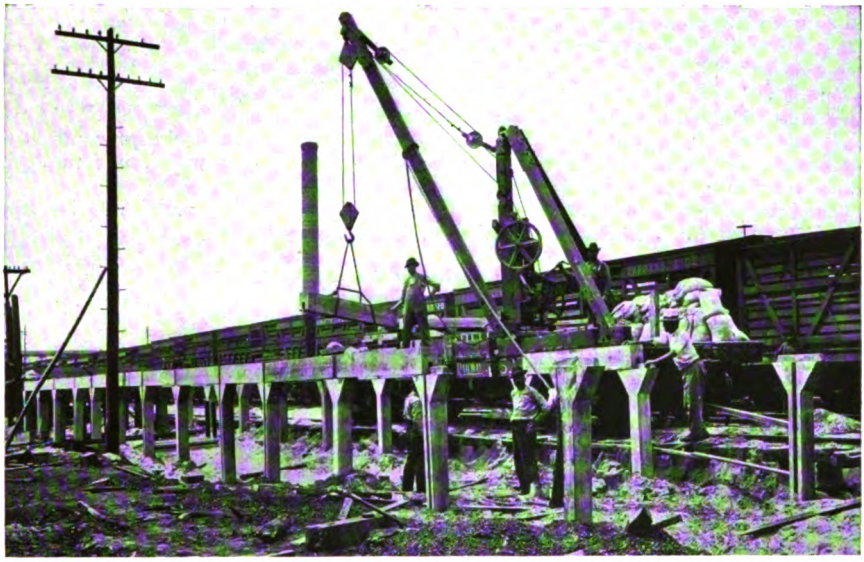
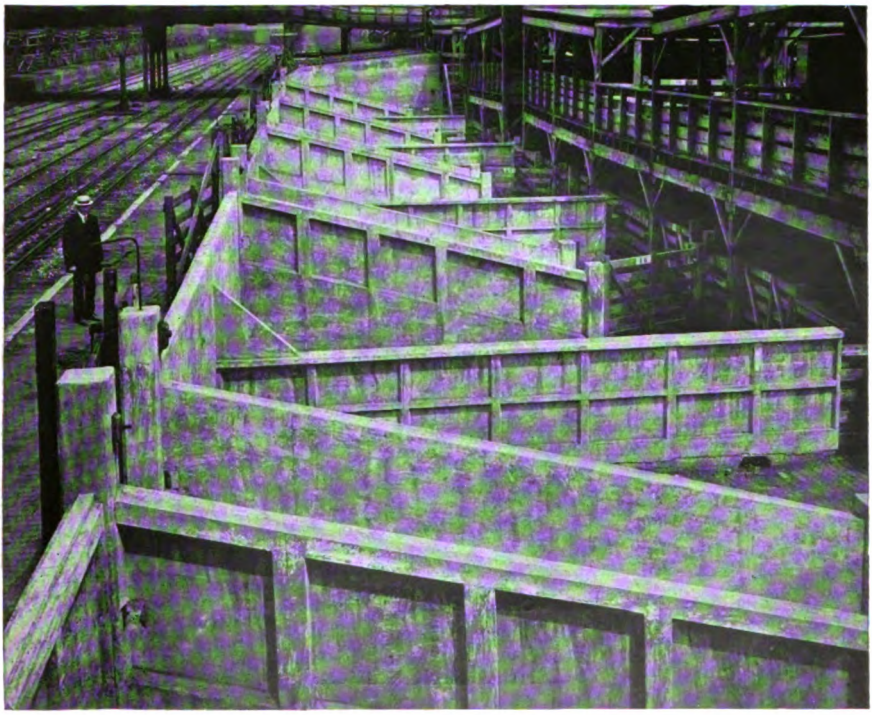
Fig. 3 shows the method of erecting one of the receiving platforms. This work was also done according to the system of piece construction. The views show plainly how the connections were made.





FIGS. 3 and 4. REINFORCED CONCRETE AT THE CHICAGO UNION STOCKYARDS.

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The construction of a row of cattle pens was commenced over a year ago, and represents the first attempt at cattle-pen construction in reinforced concrete. The pens throughout are of monolithic construction, the panels in the fences being 2½ in. Shallow foundations were first laid sufficiently below the frost line to ensure permanent stability under severe changes in temperature. To bond the fence to the foundations securely all vertical reinforcements were placed when the foundations were laid. No skilled labour was used in the work, since no finish was necessary after the removal of forms. For the entire work only one set of forms was used for each design, the forms being removed after 24 to 48 hours, and utilised over and over again.

On account of the fact that the concrete walls were so thin, the precaution was taken to oil the forms thoroughly to prevent absorption, and to prevent the green concrete from adhering to the forms and impairing the surface.

Our illustrations and description are by courtesy of the Editor of *The Universal Portland Cement Co.'s Bulletin*, of Chicago, U.S.A.

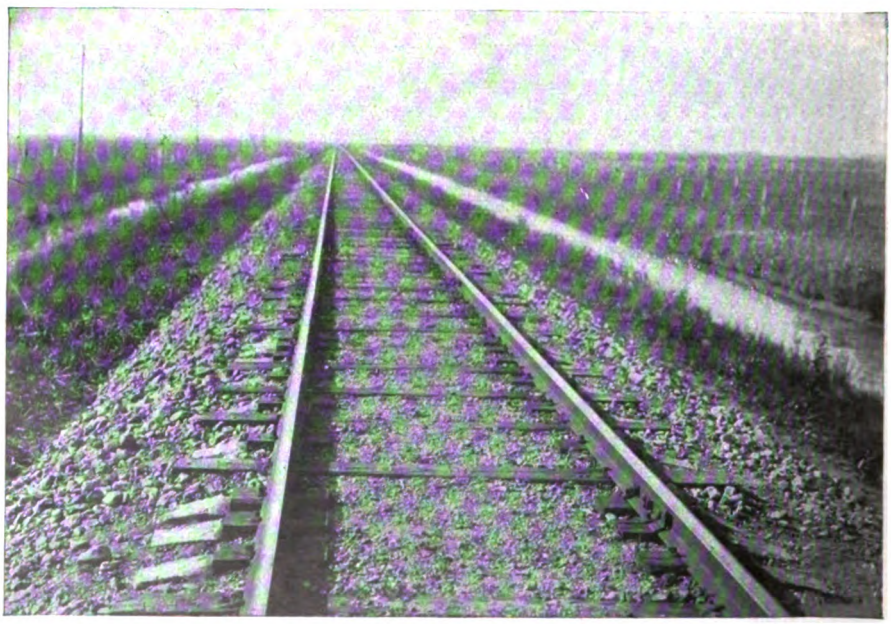
REINFORCED CONCRETE SLEEPERS.

Among the subjects discussed at the recent convention of American Railway Men, held in Chicago, was the utility of concrete for railroad sleepers.

A Committee had inspected various sleepers, and although some of them had not given entire satisfaction, it was generally agreed that concrete sleepers would eventually be made in satisfactory form and would be used in large numbers.

Through the courtesy of the *Cement Age* of New York we are enabled to present an illustration of the Percival concrete sleeper.

It will be seen that the track is in good condition, and this after two years, five months and fourteen days of wear. This track has been subjected to heavy freight traffic and six regular passenger trains daily at the highest speed.



Percival Reinforced Concrete Sleeper, Houston, Texas, U.S.A.

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD

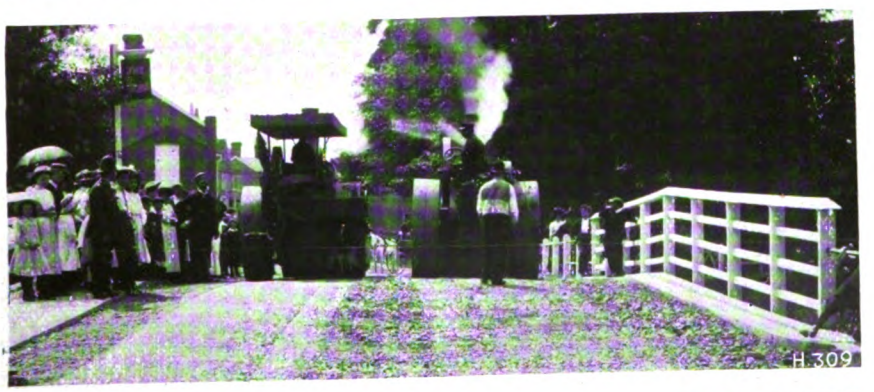
Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED

NEW BRIDGE AT EARLS COLNE, ESSEX.

THE new reinforced concrete bridge at Earls Colne, Essex, of which we show photographs, is a substantial structure 53 ft. long and 30 ft. wide, and the decking is designed to carry a test load of 200 lbs. per sq. ft. The main beams of the decking, abutment, and wing walls are carried by reinforced concrete piles 14 in. by 14 in. section, from 27 ft. to 35 ft. in length, the total number of piles being fifteen under main beams and abutment walls and ten under wing walls.

It replaces an old timber bridge, which had done duty for over a century, but which was not equal to the increased locomotive traffic of modern times.

The new structure was tested in the presence of Mr. V. W. Taylor, J.P., chairman of the County Highways Committee, Mr. Percy J. Sheldon, county surveyor, Mr. A. A. Hunt, county surveyor of West Suffolk, and others. The test consisted of two of the heaviest steam rollers of the Essex County Council being passed backwards and forwards over it, and proved most satisfactory.



NEW REINFORCED CONCRETE BRIDGE AT EARLS COLNE, ESSEX.

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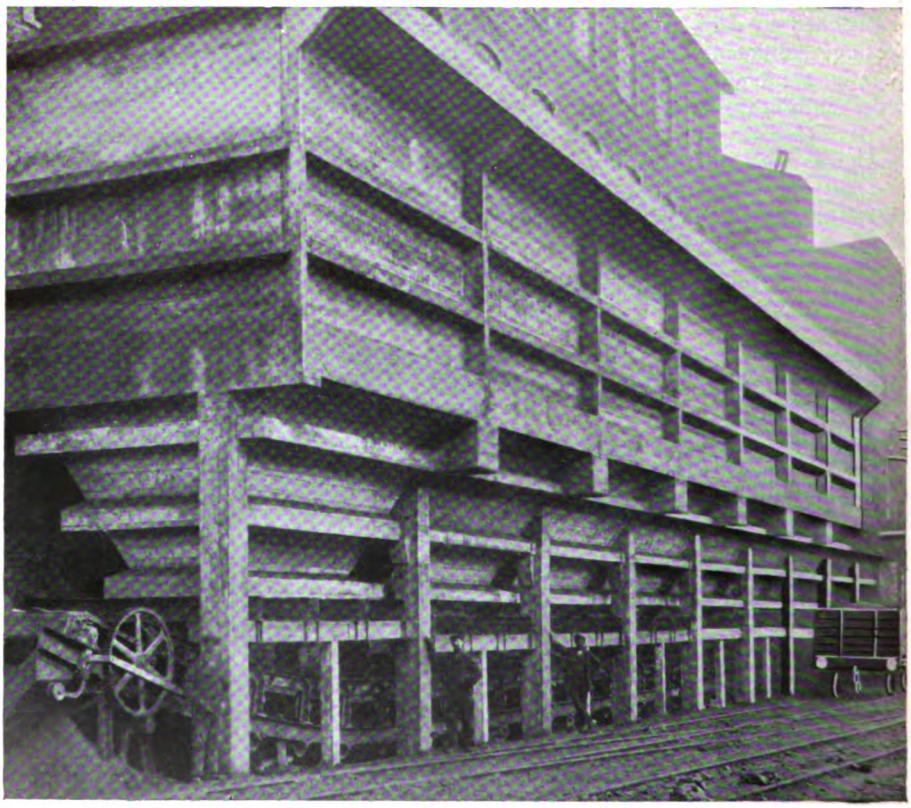
The whole of the work is in reinforced concrete, with the exception of the parapet railings, which are of oak painted white.

The work was carried out by the Yorkshire Hennebique Contracting Co., Ltd.

REINFORCED CONCRETE WASHERY BUNKERS, BARGOED.

THE seven coal bunkers illustrated in the accompanying photograph have been erected at Bargoed, South Wales, for Messrs. The Powell Duffryn Steam Colliery Company on the Coignet system of reinforced concrete.

These coal bunkers have been erected for the purpose of containing water and coal, the structure being calculated to support the weight of these materials.



REINFORCED CONCRETE WASHERY BUNKERS, BARGOED.

The total capacity of these bunkers amounts to 27,000 cub. ft. of coal. Their total length is 111 ft., width 14 ft., and height 31 ft.

It will be noted that the whole structure is supported on columns.

The work was secured in competition with steel bunkers of equal capacity.

The contractors for this work were Messrs. Heenan & Froude, Ltd., Manchester, who are licensees of Messrs. Coignet, Ltd.

We consider that of the many uses to which reinforced concrete can be economically put there are few more marked than its application in bunkers, coal hoppers, silos, and similar works.

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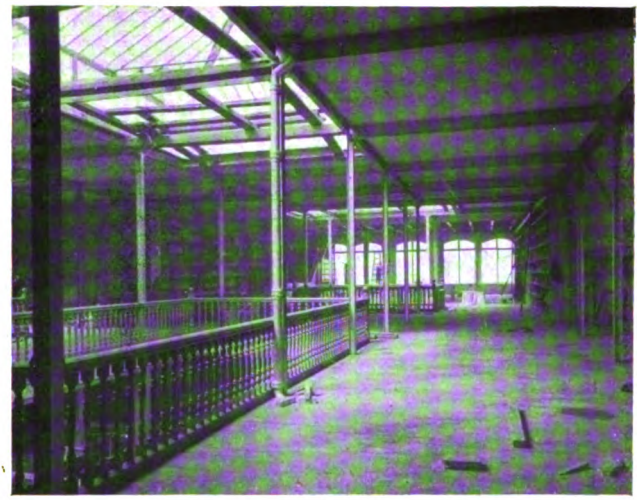
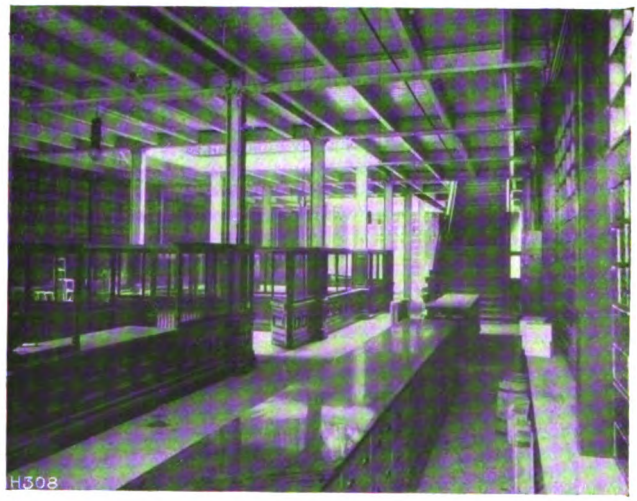
A NEW WAREHOUSE AT DUBLIN.

We are enabled to present some photographs which illustrate the constructional features of the new buildings erected in Dublin for Messrs. Thos. Dockrell, Sons and Co., Ltd. These new premises form a good example of expeditious construction of steel frame, concrete, and timber, for, after the old buildings had been gutted by a disastrous fire, which necessitated the clearing of the whole site and the rebuilding of the entire premises, with the exception of a little brick walling, which was allowed to remain, the new buildings were erected and in occupation within a few months. The building, however, unfortunately, serves as one of those examples where the modern forms of construction can be seen alongside of forms long superseded where any attempt at fire resistance is desired.





Messrs. Dockrell's New Premises, Dublin.
View of a concrete floor supported by unprotected steel framing, and a timber floor resting on similar steel framing.

Thus, whilst the large roof and certain portions of the floors and loading stages are of concrete reinforced by expanded metal, practically all the steel framing is unprotected and an enormous amount of timber and wood flooring has been used.

The building is L shaped in plan and fronts on to three roads, and the two rectangles measure approximately 150 ft. by 50 ft. and 120 ft. by 90 ft. It consists of two floors and a basement throughout with a flat concrete roof reinforced with expanded metal and asphalt. The skylights, it might be added, have wire glazing.

The suspended floors and roofs are carried by structural steelwork built up of rolled sections, and the majority of new walls are built of plain concrete.

The steel columns, measuring about 16 ft. centres on plan, are founded on concrete bases reinforced with expanded metal, the size of base and thickness of concrete

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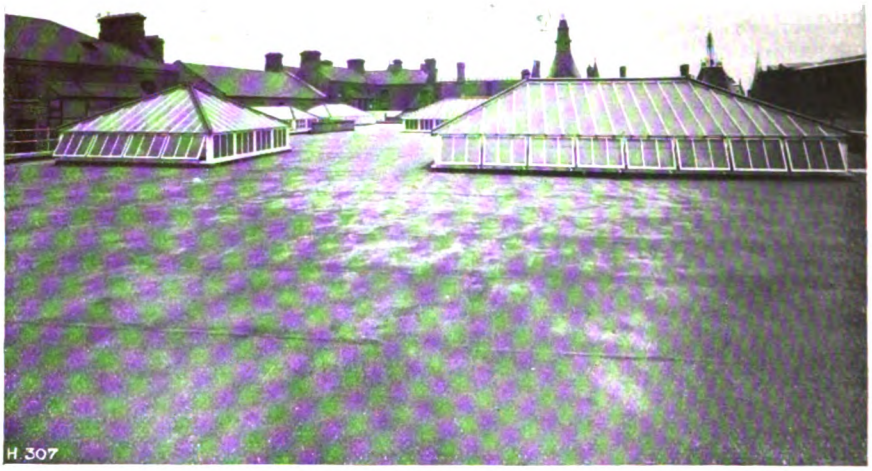
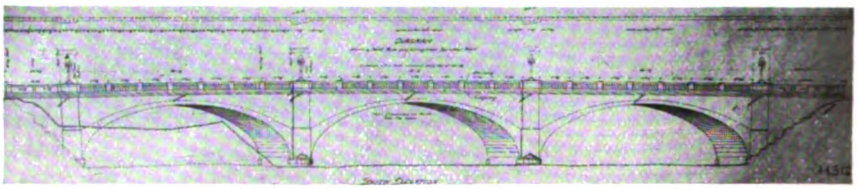
varying according to the load on the column and ranging from 6 ft. 9 in. by 6 ft. 9 in. to 3 ft. 3 in. by 3 ft. 3 in. by 2 ft. to 1 ft. 6 in. respectively in thickness, all reinforced with No. 69 expanded steel in two layers; the load on the ground being taken as about three tons per super. ft.



Reinforced Concrete Roof at Messrs. T. Dockrell's New Premises, Dublin.

The structural steelwork was supplied by Messrs. Redpath, Brown and Co., Ltd., from their Edinburgh works, while Messrs. Dockrell acted as their own contractors. Messrs. Kaye, Parry and Ross, of Dawson Street, Dublin, were the architects. The concrete used throughout was made from Knight, Bevan and Sturge's Portland cement.

Summarised, the building affords a good example of steel-framing, but so applied as not to meet with the modern views of fire resistance for structures of this class, in which the protection for all steel-framing with concrete is essential and where wood joist floors are entirely out of place.



The Macey Street Reinforced Concrete Bridge, Los Angeles.

REINFORCED CONCRETE BRIDGE AT LOS ANGELES.

As the new reinforced concrete bridge across the Arroyo de Los Pasos at Macey Street, Los Angeles, will be a very complicated engineering work more than ordinary care was required in the design.

The structure will be 264 ft. in length and have a width of 65 ft., providing for double street railway track in the centre of a 51 ft. roadway and two 3½ ft. footpaths.

The bridge has a grade of 6½ per cent. on the roadway. There are three arches, those of either end being 58 ft. wide, while the one in the centre is 66 ft. in width.

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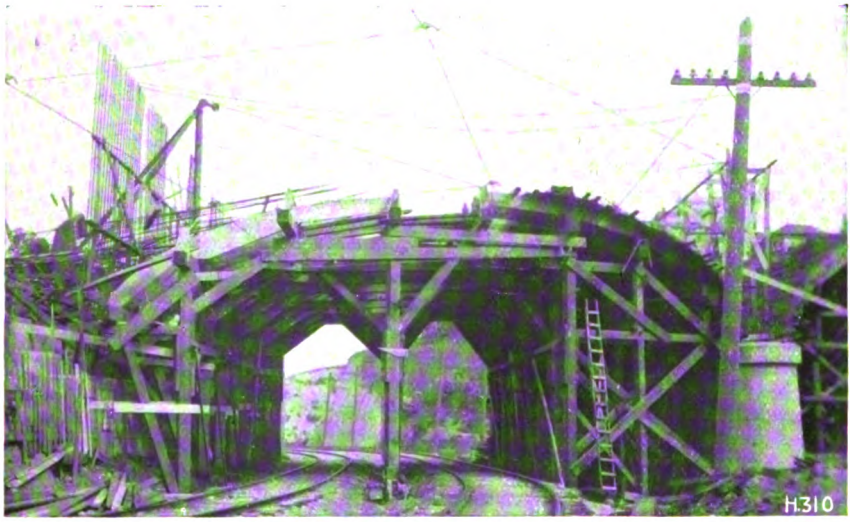
To provide a solid foundation for the piers 200 piles were driven under each one, the piling sinking to a depth of about 15 ft. The piers extend 25 ft. above the ground. They are 6 ft. thick at the springing lines and 70 ft. long. The piers and abutments have been finished and the arch centres are now being erected.

The flooring will be covered with earth to a depth of $3\frac{1}{2}$ ft. The space between the piers is being used as a passage-way for the street cars of the Pasadena line, and the Pacific Electric Company intend to utilise the territory below and adjoining the bridge as a big switching yard, thus making it a centre of activity.

To facilitate these arrangements necessitated setting the piers on a 25 per cent. skew, and in order to make the roadway kerbs level at right angles the springing line of the arches rise about 2 ft. in the length of the piers.



THE MACEY STREET REINFORCED CONCRETE BRIDGE, LOS ANGELES.
(View in course of construction.)

The pier footings are reinforced with $\frac{3}{4}$-in. round steel rods $3\frac{3}{4}$-in. apart, running longitudinally with the piers—some of the rods are 70 ft in one length. They were delivered at Los Angeles in this length from Pittsburg. There are some 100 tons of round steel bars $\frac{3}{4}$-in. and 1-in. in the work.

Ornamental concrete coping and railing will be erected, and concrete lamp-posts with bronzed fitments and four globes each will be placed on each of the eight buttresses. The cost of the bridge without extras will be about $51,787 (£10,357).

The bridge railing, which was not included in the contract, will cost $2,636 (£527). Land was purchased for the approaches at a cost of $14,500 (£2,900). Other extras, such as piles, engineering, and additional labour, will cost approximately $8,000 (£1,600).

The Pacific Electric Railway, in consideration of being allowed to extend its Brooklyn Avenue line across the bridge, pays about one-third of the above.

The bridge, when completed, will be one of the most sightly structures in Southern California. It is neither the largest nor the costliest concrete bridge in these parts, but the proportions are good and the material lends itself well to the style of architecture adopted.

The bridge was designed under the direction of Homer Hamlin, city engineer, by H. G. Parker, engineer of bridges. The Union Iron Works of Los Angeles is the contractor, H. P. Smith being in charge for the contractor.

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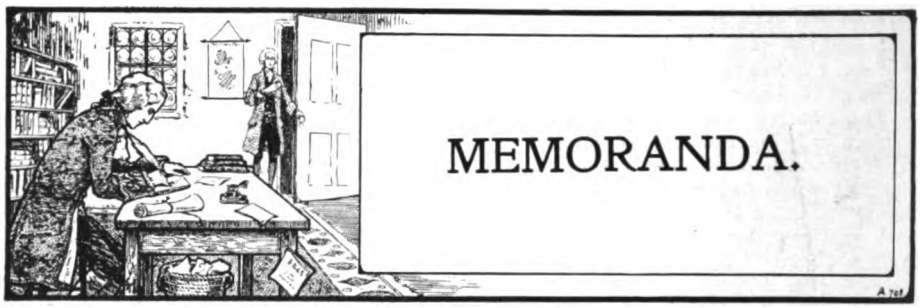

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

GENERAL.

French Commission on Lime and Cements.—The official journal of the French Government publishes an announcement of the Ministry of Public Works, Posts and Telegraphs, in which it is stated that the Commission on Lime and Cements, which was appointed in 1901, is now constituted as a permanent department of the Government. The article defines the duties of the new department. Under Article No. 1 it is ordered that the Commission shall generally supervise the composition and manufacture of hydraulic binding materials, such as cements, hydraulic limes, etc., and control the works producing the same; it shall frame the conditions governing the delivery and use of mortar and concrete and generally enquire into the question of their efficiency.

Under Article 2 the laboratories of the National School of the ponts et chaussées as well as the laboratory of the ponts et chaussées, with their personnel, shall at all times be at the disposal of the Commission for tests and experiments. The Commission can call into consultation and co-operation engineers of the ponts et chaussées and of mines, as well as manufacturers of limes and cements.

Under Article 3 the Government is to make an annual appropriation to defray the cost of the tests and experiments mentioned above.

Following the definition of the work of the Commission, the following were appointed to serve thereon:

Guerard, president, inspector-général ponts et chaussées.
Etienne, inspector-général ponts et chaussées.
Alexandre, inspector-général ponts et chaussées.
Vetillart, inspector-général ponts et chaussées.
Le Chatelier, inspector-général of mines.
De Joly, engineer-in-chief ponts et chaussées.
Mesnager, engineer-in-chief ponts et chaussées.
Feret, chief of the laboratory ponts et chaussées at Boulogne.
Candlot, president of the syndicate for limes and cements.
Lavocat, president of the syndicate for artificial Portland cement in France.
Bauchere, engineer, director of the society of cement manufacturers in France.
Gilles-Gardin, secretary, engineer ponts et chaussées.

This Commission is a very strong one, representing in its membership those corporations whose names are almost synonymous with the history of the Portland cement industry in France.

An Important Concession.—It is officially notified that the following articles may be imported free into Jamaica: Cement, which conforms to such standard as may be passed by the Governor in Privy Council; steel bars, expanded metal wire cloth, and other steel material specially manufactured for reinforcing concrete in

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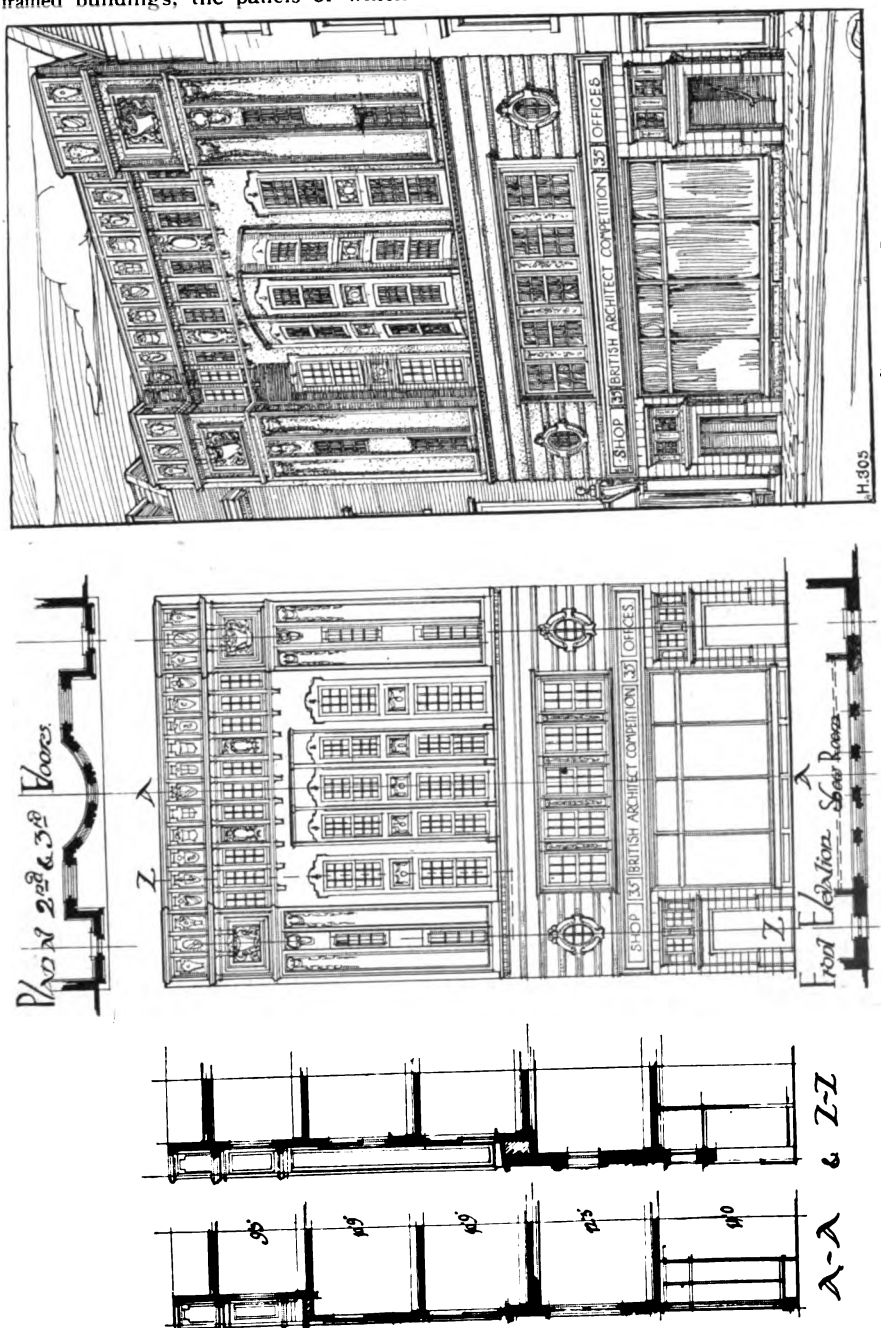
building work; wrought iron and steel work specially manufactured for the construction of the framework of the walls, floors, roofs, partitions, and stairway of framed buildings, the panels of which are to be filled in with brickwork, masonry,



ARCHITECTURAL TREATMENT OF A REINFORCED CONCRETE FAÇADE TO SOME BUSINESS PREMISES AS PUT FORWARD IN THE "BRITISH ARCHITECT" COMPETITION, BY MR. G. E. GRAYSON.

concrete, or similar non-metallic material; artificial limbs, crutches, and other appliances for the relief of bodily disablement.

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International Competition for "Earthquake-Proof" Houses.—This competition, which was arranged by the Lombard Co-operative Society for Public Works, drew no less than 214 designs, of which fifty were submitted by technical men abroad. The jury of selection, however, withheld the first premium of 3,000 lire, as they were of opinion that not one of the entrants entirely met the conditions of the programme. The second prize of 2,000 lire was awarded to the engineer A. Danusso, of Turin, and the third prize of 1,000 lire was handed to Messrs. V. Gianfrancheschi and G. Revere, of Milan. The medals offered by the Board of Public Works were awarded to Dr. Fritz von Emperger, of Vienna; Messrs. A. Susiuno and E. Bachetti, of Rome; and to Mr. E. Coignet, of Paris. *(Il Cemento.)*

Reinforced Concrete Wall.—A concrete wall 200 ft. long, 16 ft. high, and 4 in. thick, forming one side of a new quartermasters and ordnance warehouse, was placed in position recently at Camp Perry, Ohio, by the Aiken "jack" system, according to which the wall is poured in an inclined position, and later tilted to its upright position by revolving the frame or "jack" on which it rests. The wall was reinforced with ¼ in. twisted bars on 4 in. centres in each direction, held by special spacing chains on 4 ft. centres. The rods were placed in the centre of the wall. It is stated that the reinforcement was placed by two men in one day, that the pouring took 5hrs. and 10min., and that five men finished the surface in one day. It was raised 48hrs. after pouring, without developing cracks. This wall is reported to be the longest so far erected on this system.

Architectural Rendering of Reinforced Concrete Designs.—The greater use of concrete necessitates architects giving attention to the question of its architectural treatment for business premises.

It may be remembered that some time back a most interesting competition was organised—the first of its kind—by our contemporary *The Builder,* to which we referred. The subject was dealt with in our issue of November, 1908, and on that occasion the design was that of a club-house.

We now present one of the illustrations from the competition organised by the *British Architect* in respect to some business premises. This was not the first successful one, inasmuch as the premium was awarded to Mr. J. Gaff Gillespie, but we prefer the one presented, and have by courtesy of the *British Architect* reproduced it on the preceding page.

Large Reinforced Concrete Bridge Span.—The Joint Committee of the Kilkenny County Council and the Kilkenny Corporation have decided to remove the existing highway bridge across the river Nore at Kilkenny and to build in its place a reinforced concrete structure on the Hennebique system. The Irish Board of Public Works have shown their confidence in reinforced concrete by extending the period of repayment for the necessary loan to fifty years. The main dimensions of the bridge are: Total length, 196 ft.; width between parapets, 30 ft.; width of roadway, 22 ft.; footpaths, 6 ft. each. The bridge will include an arch with a span of 140 ft., one of the largest in reinforced concrete constructed in the United Kingdom. It will provide a clear headway of 11 ft. 6 in. above normal water level, and will consist of three ribs supporting open spandrils and connected by transverse beams and a continuous decking, the footpaths being carried on cantilever projections of the deck beams. The abutment walls and counterforts will rise from reinforced concrete foundations, comprising beams and a continuous slab, built up from a series of Hennebique piles, 14 in. sq. and about 35 ft. long, driven into firm strata on each side of the river, the foundation being completed by a screen of sheet piles 25 ft. long.

Painting a Cement Wall.—The following method of painting a cement wall was described at a recent convention of Canadian master painters. The building had become discoloured in places, and the joints were of a different colour from the surface of the blocks. Two parts of Portland cement were mixed with one part of marble dust, and mixed with water to the consistency of thin paint or a thick whitewash. The wall must be well wetted before the application of this paint and kept constantly wet while the material is applied, and then must be kept for a day longer, in order to make the cement wash adhere to the cement surface. The wash was applied with ordinary whitewash or calcimine brushes, and a man was kept busy playing a hose on it while the work was being done. The whole secret of success lay in keeping the wall constantly wet.

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Concrete Telegraph Poles.—Experiments with concrete telegraph poles by the Pennsylvania Railroad have met with such success that the executive officials of the line have decided gradually to extend their use over the Fort Wayne, Panhandle, and other lines west. Before many months it is possible that old wooden poles along the lines in that vicinity will be replaced by concrete. No definite sum of money has been put aside for this purpose, but it is understood that the engineering department has been given orders to prepare to use concrete poles. The instruction and improvement programme for 1910, which will be decided upon shortly, is expected to include orders to place many miles of concrete poles on the lines west.

The Sydney *Morning Herald* states that the Postmaster-General (Sir John Quick) has approved of tenders being invited for 1,000 concrete telegraph poles.

Reinforced Concrete Ships.—According to a writer in *Cassier's Magazine* the idea of building boats of concrete is not a new one. Lambot, in 1850, built a boat of this material. About eleven years ago Mr. D. B. Banks built a two-masted schooner, 65 ft. in length and 16 ft. beam, and drawing 14 ft. of water, of concrete, reinforced by multitudes of small steel rods. This craft is said to be quite swift in heavy weather, although somewhat slow in light breezes. The *Gretchen* sails in salt water, having been as far North as the vicinity of Hudson's Bay, and as far South as Cape Hatteras, if not further. She was once driven on the rocks off Cape Charles, but escaped without damage. The Italian engineer, Signor Gabellini, according to the Paris *Débats*, is engaged in constructing for the Italian Government a steam collier which is to be built entirely of reinforced concrete. Signor Gabellini has been building barges and pontoons for some years, and several examples have been illustrated in our issue of March, 1908. The steamer which he is now building is being constructed on an iron keel. Steel shanks are so fixed as to form a kind of frame for the ship, which is laced together with iron wire. Into this frame cement is poured, thus forming the hull, which will be extremely light. By polishing the outer surface of the concrete it is hoped to keep it from getting foul. The constructor claims that the hull is infinitely stronger than those of iron or wood. The upper deck and bridge are likewise of concrete, and similarly the bulkheads to the watertight compartments.

New Reinforced Concrete Bridges.—It has been resolved to replace the present timber bridge over the Stour at Cattawade by a reinforced concrete structure 25 ft. in width and capable of carrying a load of 35 tons.

The Warrington Town Council have decided to invite plans and specifications for the erection of a reinforced concrete bridge, 70 ft. long and 80 ft. wide, over the Mersey at Bridge Foot.

Concrete Cable Conduits.—The Union Electric Light and Power Company, of St. Louis, U.S.A., have been using concrete cable conduits for the past few years. The moulds consist of 16 ft. sections of lumber, held down by suitable weights in the duct form supports, which have previously been set to grade and aligned in the bottom of the trench. Concrete is then dumped into the trench, suitably rammed and puddled round the forms, and finally struck off level with the tops of the moulds. After the concrete has set, the moulds are removed by lifting them up and out of the concrete.

Storage of Oil in Concrete Reservoirs.—The following notes concerning the storage of California or crude oil in concrete reservoirs may be of interest. A 1,000,000-barrel reservoir, lined with concrete, has recently been completed at Port Richmond, Cal., and one of 800,000-barrel capacity is under construction near Bakersfield. The practice is to excavate the earth, which in most fields is a sandy loam, porous and very dry, to about one-third the depth of the proposed reservoir. With the material removed, a levee is built round the excavation, having side slopes of 1 : 1½ on both faces. The bottom and sides are then covered with about 3 in. of concrete, often reinforced with expanded metal or some equivalent. Small cracks that occur at the junction of the sides and bottom and along the line between the cut and embankment soon become filled with sediment and are believed to permit the leakage of very little oil. A number of such structures in Southern California have recently been examined and no signs of depreciation in the quality of the concrete were found.

Reinforced Concrete Water-pipes for High pressure Service.—Several tests of reinforced concrete water-pipes for high-pressure service have recently been made in the United States and these have proved so satisfactory that the American Govern-

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ment has decided to install a two-mile pipe line of reinforced concrete in one of its irrigation projects. The experiments tend to prove that reinforced concrete is not only the most satisfactory kind of pipe for high-pressure service, but that it is also the cheapest. Bearing on the same subject, the Denver Improvement Association has also reported favourably on the advantage of reinforced concrete in preference to clay pipes. The reports of the different city engineers show that no ill-effects have ever been found in well-made cement pipes from acids or alkalies, nor do concrete pipes which have been exposed to alternate wetting and drying in salt water become affected by the strong alkalies in same.

King's College, London, and Reinforced Concrete.—We have received the syllabus of the Division of Architecture of King's College and observe, with interest, that the lectures on advanced construction and sanitation include reference to reinforced concrete, but we would suggest that the term "reinforced concrete" should be used in an educational curriculum instead of "ferro-concrete," which appears on page 14 of the syllabus.

New Reservoir.—The Society of Engineers recently visited the new power station in course of construction for the Hydraulic Power Company at Grosvenor Road, Westminster. Messrs. Ellington and Woodall, MM.Inst.C.E., are the engineers and Messrs. John Mowlem and Co., Ltd., the contractors, whilst Messrs. Mouchel and Partners, Ltd., have been responsible for the design of the concrete work.

Of the reinforced concrete work the reservoir is of primary interest. It is arranged in six compartments, each about 100 ft. long, 38 ft. wide, and 16 ft. deep, the top water level being the level of the highest known tides. The construction is so designed that the vertical walls are strong enough to resist the water pressure when each or all the compartments are full without external support of any kind. The thickness of these walls is only 12 in. tapering to 8 in. at the top. The base is supported by the floor and the head by a horizontal beam forming a gangway, and these beams are augmented by tie beams at intervals across the compartments.

The total dimensions of the reservoir are about 200 ft. by 120 ft. The other reinforced concrete work in connection with the station comprise a covered roadway over the pipe subway, a coal store and filter room floor and boiler blow-off pit. Reinforced concrete has been used wherever it could be easily and economically applied to this work, and the visit of the Society was thus an eminently instructive one.

Reinforced Concrete Work for School Buildings at Cardiff.—The Cardiff and District Architects' Association were recently invited by Messrs. Teather and Wilson, architects, of Cardiff, to visit the reinforced concrete work, which is being constructed on the Coignet system, at the Newport Road Intermediate School for Boys.

The members present were taken over the work, and an explanation was given them of the methods employed for the construction of floor slabs, beams, pillars and balconies.

Visits of this kind do much to assist the members of the technical professions concerned in understanding the practice of reinforced concrete construction.

Reinforced Concrete Houses.—We have received an instructive pamphlet dealing with architectural development in the reinforced concrete house from the pen of Mr. Benjamin A. Howes, of New York. The article, which is well illustrated, is reprinted from *The Architectural Record of America.*

Chicago Cement Show.—The third annual Cement Show in Chicago will again be held in the Coliseum on February 17th to 23rd, 1910. Elaborate arrangements are already under way to make the next exhibition even better than the last.—The American Society of Engineering Contractors have accepted an invitation from the Cement Products Exhibition Company to hold their next annual convention in Chicago during the Cement Show. The days upon which their meetings will be held are February 24th, 25th, and 26th. Mr. Geo. W. Jackson is President of the Society.

Cementology is the title of a small leaflet issued by the Whitehall Portland Cement Co., of New York and Philadelphia, and contains much interesting and instructive information dealing with the manufacture and uses of Portland cement.

TRADE ANNOUNCEMENTS, CATALOGUES, etc.

British Uralite Company's Products.—With the increasing interest in fire protection, the possibility of obtaining a simple protective means to this end, economically, should be of interest.

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We have received particulars from the British Uralite Company (1908), Ltd., dealing with their three primary products, namely Uralite, Asbestone and Asbestos-cement roofing tiles. All three products have not only the advantage of possessing high fire resistance, but are non-conductors, clean and dry, and lend themselves readily to fixing. So far as Uralite and Asbestone are concerned, these materials are made in flat sheets up to 6 ft. × 3 ft. in size and from 1-16 in. to 1 in. in thickness. The Asbestos-cement roofing tiles are made in several stock sizes.

It is, of course, well known that both Uralite and Asbestone are used by our public authorities, notably by H.M. Office of Works, H.M. War Office, the Admiralty and the London County Council, and the newer products, the Asbestos-cement roofing tiles, are also rapidly finding favour both at home and abroad, one recent order for the Argentine alone comprising 200,000 of these tiles in one consignment. A roof constructed of these tiles can, by the bye, be seen at the Uralite Pavilion near the Machinery Hall in the Shepherd's Bush Exhibition.

The printed matter issued by the British Uralite Company is both interesting and instructive, and application for it should be made to the Company's head office at 16, St. Helen's Place, E.C., where samples are also obtainable on request.

The British Steel Piling Co.'s catalogue is a useful quarto publication of some sixty-six pages, which, besides giving information on the specific form of steel piling advocated by the firm in question, presents some useful general information and details, well meriting the attention of those who have to deal with piling problems. The catalogue of the steel piling, it should be added, also gives some useful information as to Electric Derrick Cranes, Steam Cranes and the Blaw Patent Collapsible Steel Centering, to which we have had occasion to refer in an earlier issue.

Messrs. Ed. Coignet, Ltd., have issued a neatly arranged and well printed pamphlet descriptive of some of their works already completed. These include washery bunkers for the Powell Steam Colliery, South Wales, and coal bunkers at Gennevilliers (Paris) and Rainham, Essex.

The Columbian Fireproofing Co., Ltd., have secured a £14,000 contract for nearly five miles of high pressure water pipes, 24 in. diameter, on the "Bonna" system of reinforced concrete for the Corporation of Swansea. In addition to the above they are constructing "Bonna" pipes, 18 in. diameter, for the Clydebank Water Trustees and also pipes of 21 in. diameter for the Belfast Corporation.

The Ransome-verMehr Machinery Company, of Westminster, have sent us an excellent catalogue comprising some 90 pages, quarto, dealing with the Ransome Concrete Mixer, which is being made at Ipswich.

The various types of machinery produced on the Ransome system are fully set out in this catalogue, and the reasons for the efficiency of the machines are not only given clearly, but they are also backed by useful technical information as to output and cost of use. Excellent plans are shown as to suitable hoisting arrangements, scaffolding and the like for the practical application of the machines.

We also note with some interest that apart from the Concrete Mixers the catalogue contains copies of a concrete "wall plank" rolling machine for making light concrete slabs for walls and partitions.

Altogether, the catalogue, not only in arrangement and subject matter, but also in printing and illustrations, does credit to its producers.

Messrs. James H. Tozer & Son, Ltd., of York Street, Westminster, have recently issued a handbook dealing with reinforced concrete design in general, and their "lock woven mesh" system in particular.

This publication, which is artistically produced and illustrated, may be considered rather as a textbook than as a catalogue pure and simple. Opening with a short history of reinforced concrete, from the time of Julius Cæsar down to the present day, it also includes simple and clearly worked out methods of calculation for the design of reinforced concrete members, which have been prepared on lines identical with the recommendations of the R.I.B.A. Report on Reinforced Concrete, together with a number of diagrams, formulæ, and photographs, notes on the properties of concrete and steel, etc. Altogether this catalogue forms a valuable addition to the library of anyone interested in the subject of concrete construction.

In describing the merits of their "lock woven mesh" system, Messrs. Tozer claim that by its employment great economy over other systems of reinforcement may

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be effected, when used in cases where it is most adaptable, such as sewers, culverts, walls, roofs, etc. Of supplementary uses to which the "lock woven mesh" can be put is that of fencing, and we suggest that this fencing material if fixed to reinforced concrete posts should make a fencing requiring a minimum of expenditure on maintenance.

The (U.K.) Winget Machine Co., Ltd., of Newcastle-on-Tyne, have sent us a well got up catalogue descriptive of their blockmaking machines and concrete mixers.

In addition to useful instructions as to the method of operating the "Winget" blockmaking machine, some good illustrations are given of buildings in connection with which these machines have been used and also of the various patterns of blocks made. The makers claim that while the speed of output of their machines cannot be exceeded their simplicity of operation is such that all the work may be done with unskilled labour, a useful point for our Colonial and foreign readers to note. The opening or closing of the mould box is done by the instantaneous movement of one lever only, there are no special bolts or fixings to trouble about.

The "Express" concrete mixer, made by the firm in question, is particularly suitable for concrete block making, and also for reinforced concrete work generally.

The First Cottbus Cement Goods and Machine Works, of Laleham Road, Catford, S.E., inform us that they have now made arrangements by which purchasers of their machines can send their workmen to Catford to be taught how to handle the machines, free of charge, with a view of obviating the possibility of owners incurring expense in experimenting with machines purchased. This is certainly a step in the right direction.

We also hear that this firm are ready to receive samples of sand and gravel from those interested in cement block making, so that sample bricks could be made for them.

Improved Construction Co., Ltd.—We understand that some of the British railway companies are now placing trial orders for sleepers of reinforced concrete, and a portion of these orders has been received by the Improved Construction Co., Ltd., of Victoria Street, Westminster. Tests have already been made in the United States, which appear to be favourable to the use of suitable reinforced concrete sleepers, and the Italian Government recently placed an order for 300,000 reinforced concrete sleepers, after having made extensive investigations on the Italian lines.

The Rib Metal Co. have issued a small pamphlet which explains the utility of rib bars for reinforced concrete. This rib bar has been designed to meet the requirements of engineers who demand a mechanical bond for their reinforcement when used in concrete constructions.

Movable Concrete Centering.—An ingenious device for movable concrete centerings has been patented by Mr. H. French, of 9 Hugh Street, Ecclestone Square, S.W. It is equally applicable to the construction of walls, floors, and roofs. The sections are made of wood, steel, etc., and owing to their simplicity the first cost is extremely small, whilst that of maintenance is practically nil. The inventor claims that, with ordinary labour, good cement, and proper mixing, concrete walling is much cheaper by these sections than brickwork at equal strengths.

CONTRACTS.

The following lists of contracts entered into are prepared from the statements transmitted to this journal by the firms mentioned below :—

R. Johnson, Clapham & Morris, Ltd.—Schools in Canada; railway work for the L.B. & S.C.R.; cottages and shop floors on Lord Egerton's estate and a tank at the Manley Gasworks, Sydney, N.S.W.

D. G. Somerville & Co.—Printing works, Blackfriars; water tower, Leicester; viaduct for Norwich Corporation; nursing home, Norfolk County Asylum; bridge at Hackney; workhouse, Romford; wharf, Portslade; school, Sheerness; wine vaults, Folkestone; factory, Wimbledon; buildings, Stepney; Warehouse, Ayrshire.

CHANGES OF ADDRESS.

Messrs. Scott & Fraser, Architects and Surveyors, formerly of 10, Basinghall Street, E.C., desire to notify that they moved their offices to 13, Old Square, Lincoln's Inn, W.C., on the 29th September.

The Perfector Bar Co., of Standard Buildings, Leeds, announce that they are taking London offices, and their address in the Metropolis is 38 Victoria Street, Westminster.

ERRATA.

In the article on a "Reinforced Concrete Torpedo Station in the Mediterranean" which appeared in our August issue one of the paragraphs might be read to describe M. Michel-Schmidt (of Messrs. Schneider & Co.) as the designer of the reinforced concrete work of this station. Mr. F. Hennebique, of Paris, informs us that it was with his firm that the idea of using reinforced concrete for this work originated, and that his firm prepared the plans for executing it on the Hennebique system.

In the article on reinforced concrete fence posts published in our July issue, we should have mentioned that in the case of wooden posts—lasting twenty years—these were for creosoted wood, which, of course, enhances the expense and gives a further advantage to the reinforced concrete post.

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THE ADMIRALTY HARBOUR WORKS, DOVER.
(General view when nearing completion.)

Frontispiece.
(Opp. Contents.)

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume IV. No. 6. LONDON, NOVEMBER, 1909.

EDITORIAL NOTES.

"DREADNOUGHTS" AND DOCK ACCOMMODATION.

WHILST naval matters and the provision of *Dreadnoughts* have been very much to the fore during the present year, the question of permanent dock facilities seems to have again escaped public attention. We hear of two floating docks about to be built, but of additional permanent dock accommodation we hear nothing definite.

It is not long since we were forcibly reminded in a monthly contemporary (*The National Review*) of the close attention given in Germany to what might be termed the "Accessories" of their naval programme, which accessories include dock accommodation and workshops, wharves, stores, auxiliary ships, etc., and primary attention has certainly been given by the German Navy Department to permanent docks and workshops. Their new docks are not only numerous and well located, but are to be of such dimensions as to allow for further material progress in the size and tonnage of battleships.

Though it may appear somewhat *ex parte* for a journal devoted to the uses of concrete to advocate strongly that greater attention should be given to the provision of permanent docks, yet we do so in no narrow spirit, but under the deep conviction that it is the permanent dock, with its necessary workshops and other repairing facilities, which must one day play an important part in the safety of the Empire.

The principal advantage of the permanent dock, apart from any question of initial cost or maintenance expenditure, is that ships can be repaired in them in a rapid, practical and business-like manner, and this is all important where time is of the greatest consideration. Apart from the maintenance expenditure required on floating docks they are all too frequently useless for the repairs necessary for certain classes of battleships when really badly damaged, and they can rarely be placed just where full advantage can be taken of first-class workshops, crane, and rail facilities.

We sincerely trust that a rumour that has reached us that additional permanent dock accommodation is to be provided for at Rosyth may be true, for to anyone who gives serious attention to the question of naval supremacy it is regrettable to think of the position we shall be in in a few years owing to lack of proper dock accommodation, and it should always be remembered that permanent docks cannot be provided under three years. It often takes five years to complete a first-class permanent dock.

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Though it may appear somewhat *ex parte* for a journal devoted to the uses of concrete to advocate strongly that greater attention should be given to the provision of permanent docks, yet we do so in no narrow spirit, but under the deep conviction that it is the permanent dock, with its necessary workshops and other repairing facilities, which must one day play an important part in the safety of the Empire.

The principal advantage of the permanent dock, apart from any question of initial cost or maintenance expenditure, is that ships can be repaired in them in a rapid, practical and business-like manner, and this is all important where time is of the greatest consideration. Apart from the maintenance expenditure required on floating docks they are all too frequently useless for the repairs necessary for certain classes of battleships when really badly damaged, and they can rarely be placed just where full advantage can be taken of first-class workshops, crane, and rail facilities.

We sincerely trust that a rumour that has reached us that additional permanent dock accommodation is to be provided for at Rosyth may be true, for to anyone who gives serious attention to the question of naval supremacy it is regrettable to think of the position we shall be in in a few years owing to lack of proper dock accommodation, and it should always be remembered that permanent docks cannot be provided under three years. It often takes five years to complete a first-class permanent dock.

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THE INTERNATIONAL CONGRESS ON TESTING MATERIALS.

In our previous issue we dealt at length with the International Congress on Testing Materials, held at Copenhagen, and summarised the proceedings, giving particulars of the papers presented, and also publishing some of the more important ones in full.

In this and future numbers we shall present further papers, some in full and others in summary, for the amount of valuable information obtainable from the proceedings of the Congress is considerable, and well merits publicity among the professions and industries concerned.

THE NEW PRESIDENT AND THE NEXT CONGRESS.

We have pleasure in announcing that the next Congress will be definitely held in the United States during the autumn of 1912, at the invitation of the American Association for Testing Materials. The president of the latter Society, Professor Dudley, of Altona, Pa., has been unanimously elected president of the International Association for the impending term of three years, an election which has caused great satisfaction among all those interested in investigations of this kind, not only on account of the Professor's great knowledge and organising powers, but also because of his personal popularity.

We have now received the official terms of the resolutions arrived at at the Copenhagen Congress, and we publish those that refer to concrete, reinforced concrete, and Portland cement.

PORTLAND CEMENT AND SEA WATER.

Notable among these resolutions, we think, was one proposed by Mr. Edwin O. Sachs, F.R.S.Ed., embodying a decision to summarise results of investigations and tests relating to the effect of sea water on Portland cement. It would appear that quite a number of papers on the subject and a large number of test results have been obtained during the last ten years, but that there is nothing available actually summarising the position of affairs in both hemispheres. If such a summary could be obtained it would be most useful, particularly if supplemented, as resolved by the Congress, with a tabulated statement of the effect of sea water on actual structures of more than 25 years standing. It is to be hoped that all members of the technical professions to whom inquiries may be addressed with a view of collecting the necessary data will give every possible assistance, so that the desired record may be obtained.

THE COPENHAGEN CONGRESS RESOLUTIONS.

The following were the resolutions:—

Reinforced Concrete.—The Congress thanks the International Commission on Reinforced Concrete for the work already done and invites them to continue upon the plan described by Professor Schüle, and expresses the wish that the Committee be supported financially by the competent institutions and authorities.

Testing Cements by Prisms.—The Congress thanks the Committee entrusted with this question for the work already performed and recommends them to continue their investigations on the same lines with due consideration of the results obtained by the Hungarian Committee, to which the Congress expresses its warmest thanks. The Congress expects that the Committee will be able to propose to the next congress a definite method of using plastic mortars for the testing of cement.

Constancy of Volume.—The Congress decides to recommend the method of *Le Chatelier* as the standard accelerated test for the constancy of volume of cements.*

Accelerated Test of the Strength of Cement.—The numerous hot-water test-results given are in fact so contradictory, that this test appears too unreliable to admit of its being employed for rapid tests made to determine the strength of hydraulic cements.

* Adopted under protest of the members from Germany.

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Under these circumstances the Congress does not recommend further pursuing the question of the applicability of the hot-water test for rapid tests of the strength of hydraulic cements.

On the other hand, the experiments of Mr. Deval have once more demonstrated how valuable this test can be for information as to the constancy of volume.

Finest Particles in Cement.—The Congress begs the Committee entrusted with this question to continue their work on the adopted lines and to report on the results at the next congress.

Standard Sand for Portland Cement Tests.—That a Committee be appointed to investigate whether or not an International standard sand be possible, and if not, to secure information showing the comparative value of the different national standard sands.*

Cement in Sea Water.—The Congress recommends the appointment of a small committee—

a To obtain by December, 1910, any additional information or supplements to the reports presented at the Congress of Copenhagen they may require;

b To summarise these reports and supplements and present the summary of results in a brief form to the next congress;

c To collect information on the effect of sea water on Portland cement sea structures of more than 25 years' standing;

d To arrange for certain tests, as proposed by Mr. Leduc, on the effect of sea water on specially prepared cement.

THE ARCHITECTURAL ASSOCIATION AND MODERN CONDITIONS OF BUILDING.

We congratulate the Architectural Association on the excellent presidential address presented at the opening meeting of the current session by Mr. Henry Tanner, F.R.I.B.A., on his accession to the chair of that society.

One section of Mr. Tanner's address was devoted to "modern conditions of building," and it was pleasant to hear a few plain, straightforward words as to the necessity of architects designing their work to suit modern requirements.

That the younger generation of architects should be plainly told that it is no use preparing designs to-day to meet conditions of twenty years back is exactly what is wanted if the work of the architectural profession generally is not to still more rapidly decrease than it has already done during the last decade. Large employers of labour and building owners often find that they can get what they want in the way of sound building more effectively and more economically by either employing a civil engineer or by going straight to some large contracting firm, without taking any professional advice or at the most having the assistance of some member of their permanent technical staff.

We give an extract from Mr. Tanner's address, and recommend it strongly to the members of the architectural profession as a whole. If they still desire to in any way influence the building development of the country as far as our large industrial and business structures are concerned they had better take Mr. Tanner's advice to heart :—

ARCHITECTS AND REINFORCED CONCRETE.

"The strides made in reinforced concrete . . . . . have been prodigious, and though up till recently this type of construction has been utilised chiefly for engineering work, its influence is now being felt in our architecture, and this opens up a very wide question for consideration, for if this medium is going to be, as I think, the one utilised in our larger architectural works, we shall either have to take up the study of this form of construction with its attendant possibilities, or we shall find there will come into existence a reinforced

* Committee No 42 has been entrusted with this matter.

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concrete specialist who will take over the general construction of the building, and the architect will be relegated to the decoration of the interior and the design of the exterior.

ARCHITECTS AND MODERN CONDITIONS.

"This again raises a point of supreme importance which we are sometimes inclined to overlook. We must design our work to suit modern conditions. It is impossible to insist on the acceptance by the public of the type of work which was suitable even twenty or thirty years ago; we have to face the problem and accept the present conditions and endeavour to treat them architecturally, instead of attempting to make modern requirements bend the knee to preconceived ideas of architectural treatment, and surely this can be the one way to evolve a style of architecture of our own, which can only be good if suitable to the conditions of the country and the requirements of the people. . . .

ARCHITECTURE AN ART AND A SCIENCE.

"Architecture, we all know, constitutes an art and a science, and every year we live the latter component asserts itself more forcibly and will not be denied; it is becoming more closely interwoven with the artistic part of our work, and has a very material influence on the result, and we cannot shut our eyes to the fact and attempt to work only for the artistic. We can only produce an unsatisfactory result where we do not boldly tackle the problem with all the attendant difficulties; we cannot elect to deal with any question from the particular point of view which we desire, to the exclusion of the less interesting but none the less essential factors."

THE BELGIAN CEMENT TRADE.

SIR CECIL HERTSLET—our British Consul-General at Antwerp—in his annual report on the trade and commerce of Belgium for the year ending June 30th, 1909, refers to the year as the worst ever known in the Belgian cement trade, and attributes this to some extent to the straitened financial situation, but more largely to the competition offered to Belgian cement in the markets where it used to predominate. There appear to be signs of some improvement, and it is stated that the demand for internal consumption is likely to be fairly good for some time to come, on account of numerous constructional works throughout Belgium which are being made or in contemplation. The capacity of the existing manufacturing plants, however, is largely in excess of the home requirements, and it remains to be seen whether the Belgian manufacturer can regain the far-distant markets which to a large extent have been lost in recent years.

BELGIAN "NATURAL CEMENT."

So far as the United Kingdom is concerned Belgian "Natural Cement" is now becoming almost a thing of the past, the imports having fallen from 233,986 tons in 1904 to 83,544 tons in 1908, and they will certainly be still lower for the current year, as only 51,189 tons were imported for the nine months ending September last.

That the Belgian manufacturer still pursues his policy of attempting to foist this spurious cement as genuine artificial Portland cement of English manufacture is obvious from the following extract from Sir Cecil Hertslet's report :—

> "I will refrain from any observations in this report upon the methods of certain Belgian cement manufacturers in disposing of their goods in a manner tending to indicate a source of British origin. I have so frequently drawn attention to the matter in my annual reports on the trade of Belgium that there is nothing further to be said on the question, and repetition of the same complaints and statements is wearisome and unavailing. However, the great demand for Belgian cement which used to obtain in the United Kingdom is undoubtedly becoming much less, whatever the reason for the decline, and the Belgian manufacturer has had to search further afield for markets for his produce."

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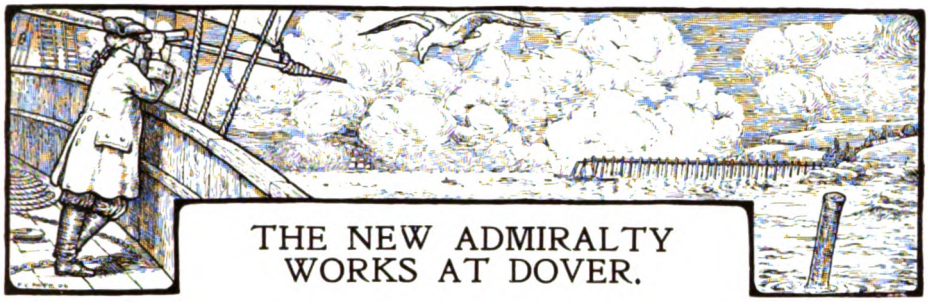

THE NEW ADMIRALTY WORKS AT DOVER.

The Admiralty Harbour Works at Dover, referred to in the following Article, are the most notable of their kind in the British Isles. The Illustrations selected for reproduction have been obtained by the courtesy of our contemporaries, "Public Works" and "The Sphere," as also through the kind agency of Mr. Harold J. Shepstone.—ED.

THE Admiralty Harbour Works at Dover, which saw their completion last month, when H.R.H. the Prince of Wales attended a special ceremony to mark the event, have been the subject of innumerable descriptions and illustrations in the daily, weekly, and technical Press. It is, therefore, not our intention to attempt a general description of these all-important works, in respect to which the whole of the pages of this issue could easily be filled, but we will limit ourselves to presenting a few specially selected photographs, and giving some data that have special reference to the use of concrete on this notable piece of civil engineering.

The Dover Admiralty Works are now perhaps the most notable and extensive example in the British Isles of the national and commercial utility of Portland cement as applied to great sea structures. There is, so far as we can remember, no individual piece of harbour work that so effectively demonstrates the useful and economic application of Portland cement concrete under difficult circumstances. No illustration can properly indicate the extraordinary extent of these works, for what can be seen of them, even at low water, is but a small proportion of the work as a whole. Apart from their extraordinary extent, it should always be remembered that we here have piers and breakwaters for a harbour, the bottom of which is some 40 ft. below low water level, the foundations, in fact, being as deep as 49 ft. below that datum.

Some 610 acres of water have been enclosed by the harbour works, and the perimeter of the harbour measures 4¼ miles. The length of the Admiralty pier extension alone is over 2,000 ft., that of the Eastern Arm over 2,900 ft. and that of the Southern Breakwater over 2,400 ft.; whilst the amount of land reclaimed measures no less than 22 acres.

Just as photographs, however, can in no way show the extraordinary extent of this work, to which over ten years were devoted with considerable industry, so it may also be said that figures scarcely explain the amount of effort and material employed.

Nevertheless, to give some additional data, it would perhaps be well to realise that not less than 74,000 of the huge concrete blocks, which form such a feature of the Admiralty Works, had to be used, representing approximately a total of one and a half million cubic yards of concrete, and weighing about two

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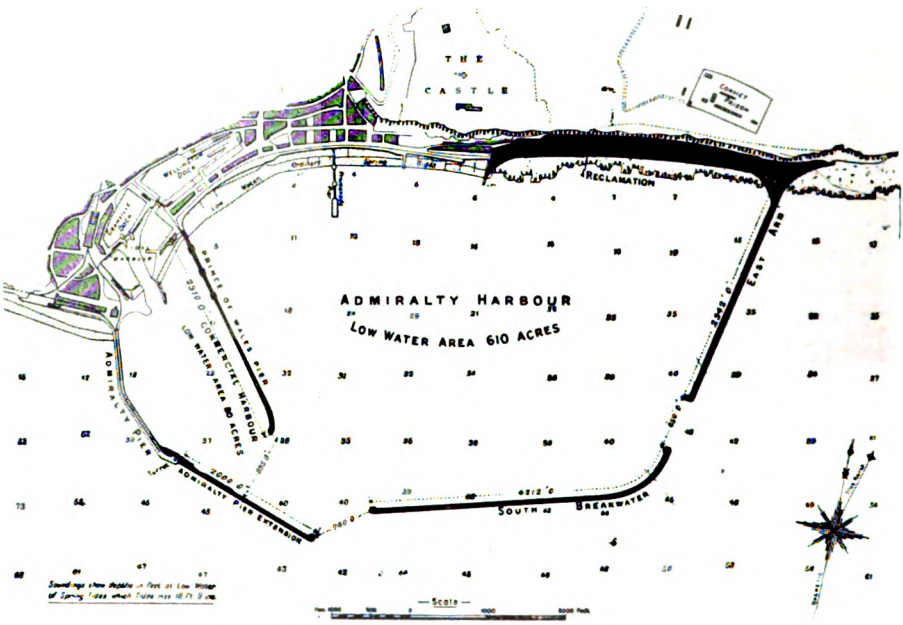
and a half million tons. In order to produce this amount of concrete we understand that some 260,000 tons of Portland cement were used, whilst 1,900,000 cubic feet of granite alone were used for facing purposes.

As to the general aspect of the design of this harbour we have little to say in view of the detailed descriptions and arguments that have already appeared elsewhere.

We show a diagram below giving the principal sections of the breakwaters, and would only mention that, generally speaking, the bottom of the Harbour Works was good.



THE ADMIRALTY HARBOUR WORKS, DOVER.
General Plan of Harbour Works (new work is shown in black).

The Eastern Arm, the Admiralty Pier Extension, and the Southern Breakwater were all three built up of Portland cement concrete blocks of various sizes and of weights up to about 40 tons, the proportion of Portland cement to aggregate being as 1 to 6. The various courses of concrete blocks were bonded together by a careful arrangement of fitting together blocks of different sizes. The outside of the blocks was, however, secured by Portland cement concrete joggles having the proportion of 1 of cement to 4 of aggregate, and besides this Portland cement grouting was used on all the work above low-water level.

When we mentioned that the average depth of the harbour was about 40 ft. it should have been stated that some of the blocks extend to 47 ft. below low water on the Admiralty Pier and to 49 ft. below low water on the Southern Breakwater. The width of the work on the piers and breakwater ranges as between 52 and 57 ft., and in order to protect the footings rough concrete block aprons have been provided. The tops of the piers and breakwater range from 40 to 43 ft. width. On the Admiralty Pier extension and on the Eastern Arm

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there are special parapets. Granite, as indicated, has been used for facing, and this material has also been used largely in these parapets.

As to the progress of the work, it was, comparatively speaking, most rapid, for all who are conversant with the extraordinary conditions of sea and tide in this district must realise the difficulty of doing work at all excepting in fine weather.

THE ADMIRALTY HARBOUR WORKS, DOVER.
(Admiralty Pier Extension in course of construction.)

The first work comprised reclaiming the 22 acres referred to above, but simultaneously with this reclamation operations were started at the Admiralty Pier extension.

The difficulty of bringing material together was considerable, and for the Eastern Arm and the reclaimed land the block yard was at first located at Sandwich. Later on a large block yard was arranged for on the reclaimed land

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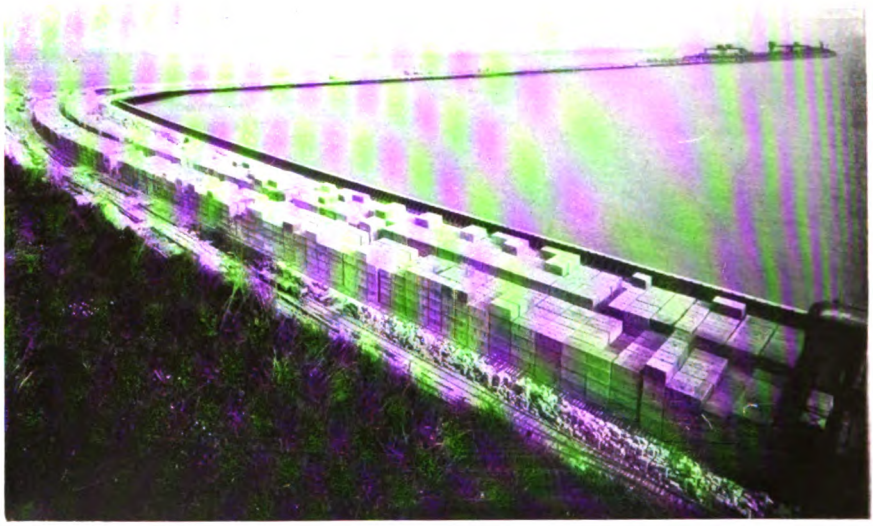
referred to. For the Admiralty extension there was another blockyard near the South Eastern Railway Station.

The aggregate, it should be mentioned, comprised shingle and sand from

View of Eastern Arm and Main Block Yard.



Staging and Appliances for Forming the Foundations (see Crab, Diving Bells, etc.).

THE ADMIRALTY HARBOUR WORKS, DOVER.

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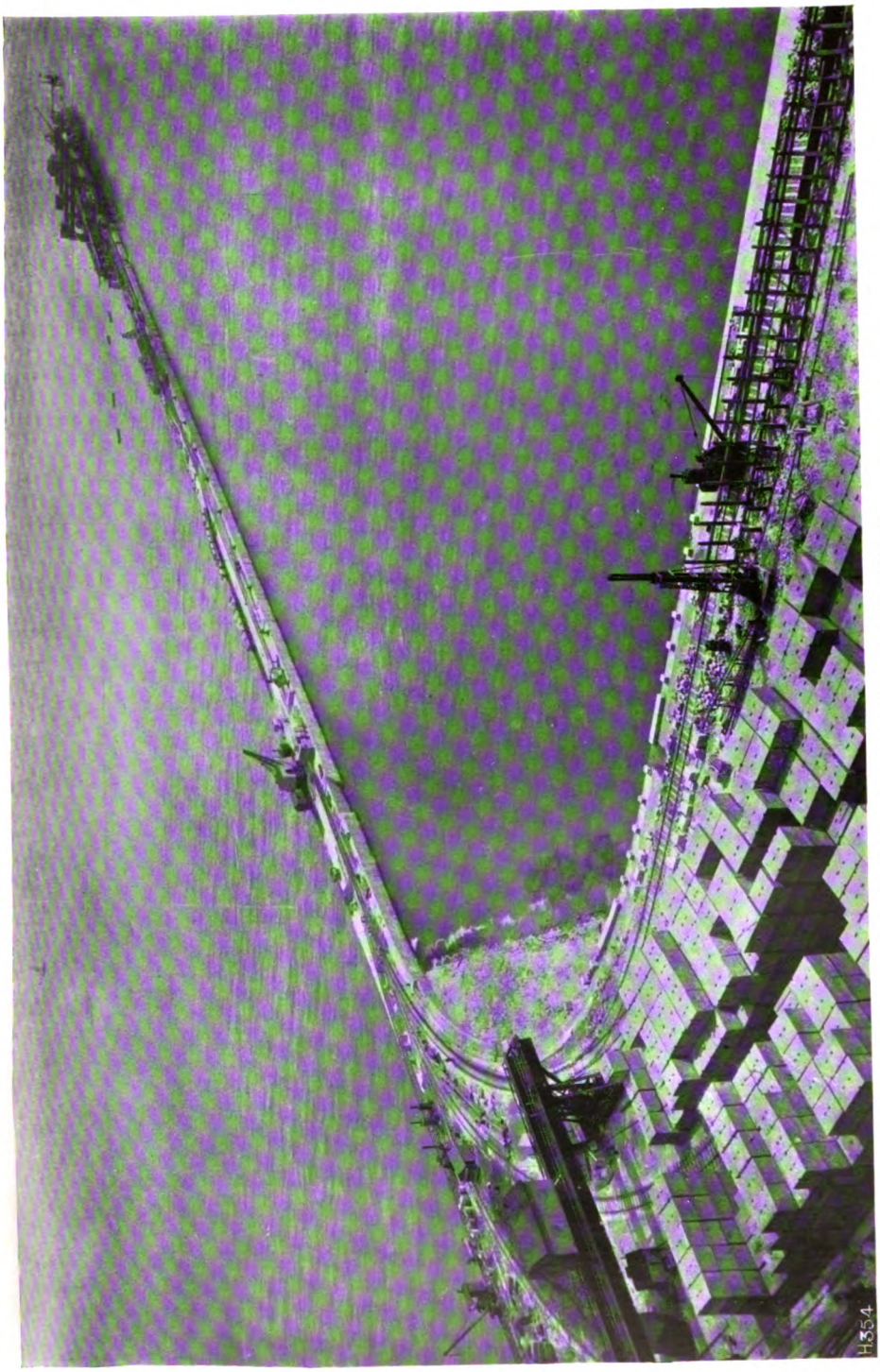

THE ADMIRALTY HARBOUR WORKS, DOVER.
View of Eastern Arm, nearing completion.

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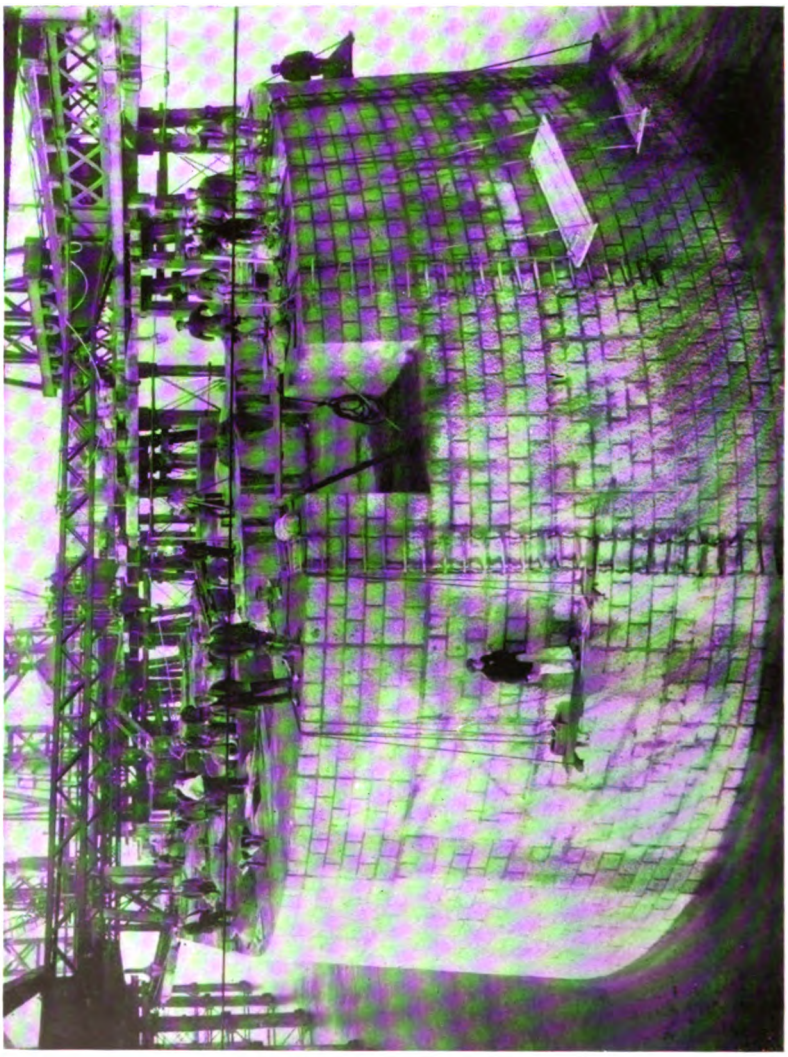
Sandwich, as far as the blocks for the reclamation work and the Eastern Arm were concerned, and we should perhaps state that electrically driven Messent concrete mixers were used. For the Admiralty extension the aggregate comprised shingle and sand taken from the foreshore at Rye and Dungeness, but, as the mixture was somewhat coarser than that which was obtained at Sand-



THE ADMIRALTY HARBOUR WORKS, DOVER.
Pier Head faced with granite, nearing completion.

wich, shingle from the latter place was mixed with it, the object being to have identical consistency and strength in all the concrete blocks used on this job.

As to the history of the work, the contract was given to Messrs. S. Pearson & Sons, Ltd., in 1897, after a number of years had been spent on preliminary designs, the final design being that submitted by Messrs. Coode, Son & Matthews

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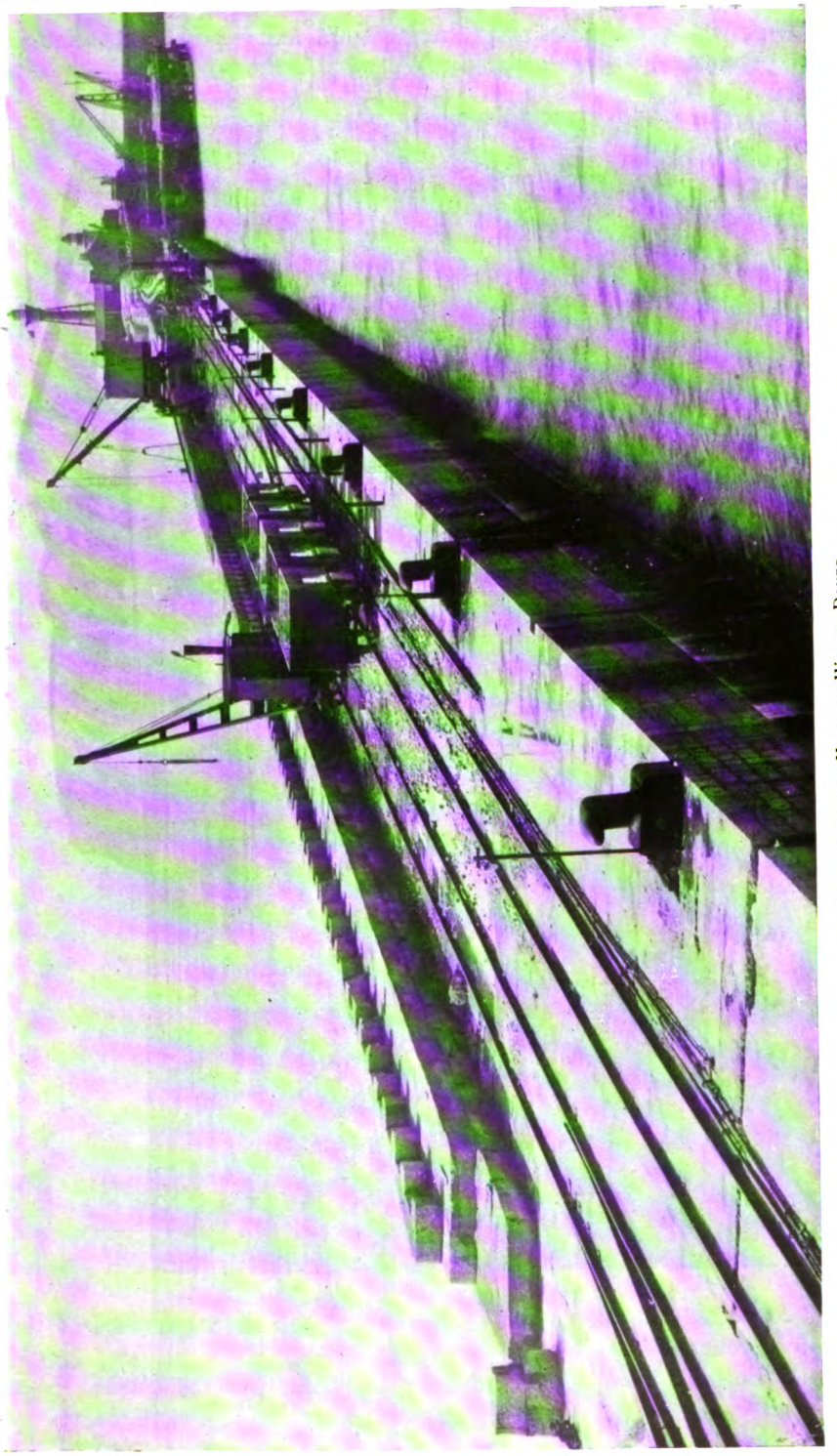

THE ADMIRALTY HARBOUR WORKS, DOVER.
View of Admiralty Pier Extension, nearing completion.

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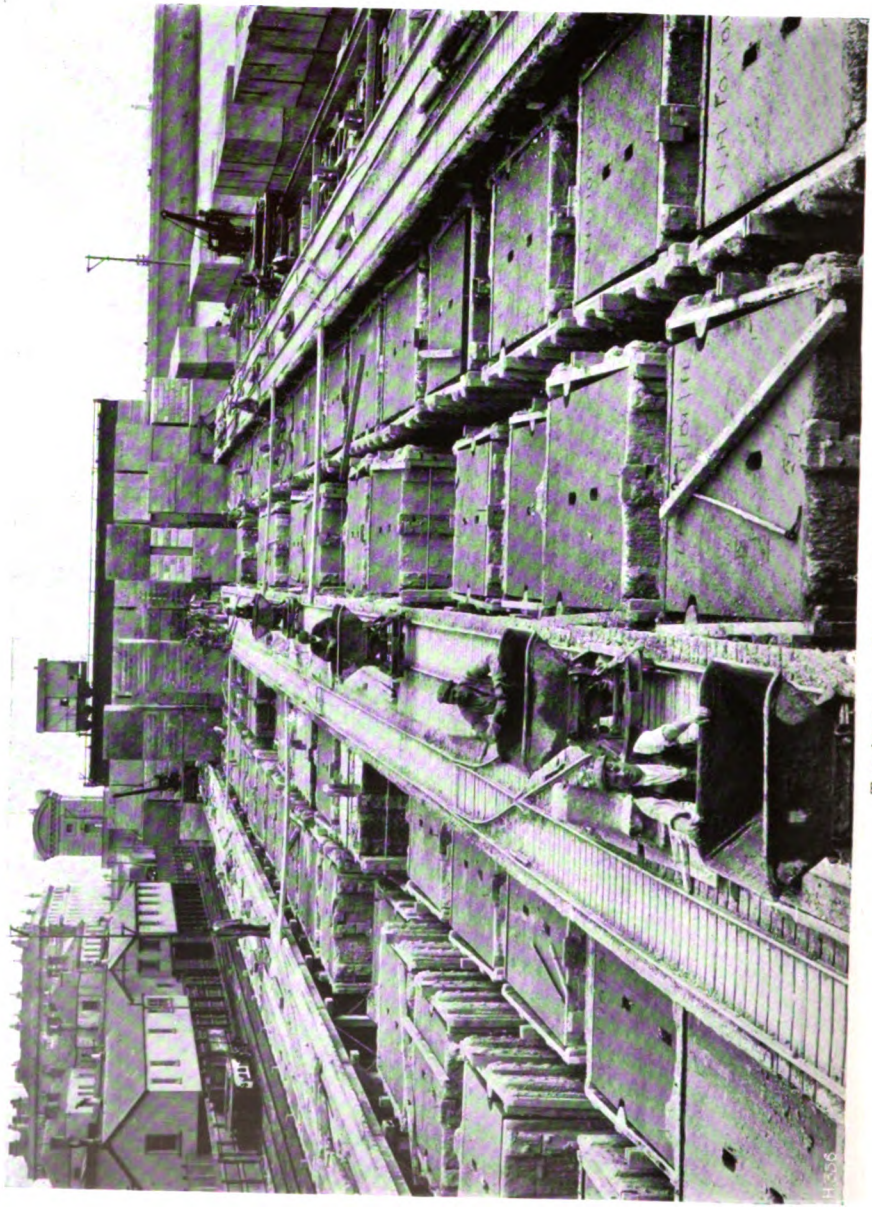
in 1895, which was practically executed with but very slight variations as to the openings to the harbour. Sir William Matthews, K.C.M.G., of that firm,



THE ADMIRALTY HARBOUR WORKS, DOVER
The Block Yard for the Admiralty Pier Extension.

was connected not only with the design but with the supervision of the work until its completion.

Colonel Sir Henry Pilkington, K.C.B., R.E., was the engineer-in-chief to

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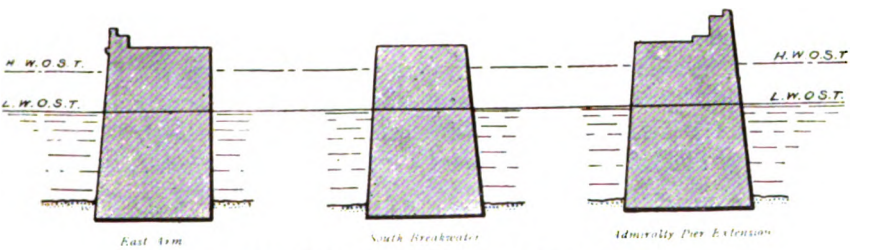
the Admiralty (Loans) when operations were started, and he was succeeded by Colonel Sir Edward Raban, K.C.B., R.E., the present Director of Works.

Several superintending engineers held office, and latterly Mr. C. H. Colson, M.Inst.C.E., was appointed in this capacity, and is still stationed at Dover.

Mention should perhaps be made of the very important *rôle* played by the divers in connection with these works, and very great credit should be accorded to Messrs. Siebe Gorman & Co., whose appliances were used, and to whom we are also indebted for illustration on page 382.

At the ceremony which the Prince of Wales attended we were particularly pleased to observe that one of the divers was presented to His Royal Highness, also some of the foremen who had been so efficient in their work. There is no doubt that in these times the actual worker on great structures of this kind should have that attention given him which he merits. The Prince of Wales, by honouring several of these workers, certainly did what was both a most politic and, at the same time, a very courteous action, which, we believe, was fully appreciated by the large majority of the workmen who helped in the completion of this great national undertaking.



DIAGRAMMATIC SECTIONS OF THE PIERS AND BREAKWATERS.

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We have frequently had occasion to refer to the advantages of concrete for fire-resisting building construction, but having regard to the unfortunate controversy over the New York Building Code, in respect to which a number of the Aldermen appear to have been showing a peculiar preference for terra-cotta, we think it advisable to give some particulars as to what has actually been going on in New York, and also to summarise the views of the two leading authorities on the subject of fire-resisting building construction in the United States, namely, Professor Ira H. Woolson and Professor Norton. The cinder concrete so frequently referred to in the article is practically equivalent to our coke-breeze concrete.—ED.

THE NEW YORK BUILDING CODE.

THE Building Code of New York has been the subject of protracted controversy. It is only ten years old and two attempts have been made to entirely remodel it. In other words, it is recognised that the code is not up to the standards with which building practice in a large and progressive city should comply, yet the attempts to alter it have met with disaster. Nearly £40,000, we are told, have already been expended on expert commissions to revise it.

The reasons for these unsuccessful attempts are unfortunately not very creditable to the New York administrators, nor do they speak well for the manner in which public affairs are conducted in that city. Technical matters are made the subject of political and financial polemics, and, above all, the old faction fight between the brick and terra-cotta industry, on the one hand, and those interested in the concrete and reinforced concrete business on the other, has been conspicuous in a form as distasteful to the better professional elements of America as it is amusing to the onlooker abroad.

In the latest attempt the terra-cotta interests tried to obtain two important restrictions for reinforced concrete construction; in fact, the proposed alterations were of such a nature as to bear unduly hard upon buildings erected in that material. For instance, it was suggested that the height of reinforced concrete structures should be restricted to 85 ft., and that the thickness of floors should be not less than $\frac{3}{4}$ in. per foot of span. A large number of experts testified to the hardship that would ensue in the event of the restrictions being passed, but in face of well-merited criticism and ridicule the Board of Aldermen recommended the adoption of clauses to this effect.

Had it not been for the Mayor, who had the necessary powers and who in his wisdom vetoed the whole revised code, the proposed absurdities would have become law.

It was, of course, realised that many of the provisions of the proposed code were excellent, but the most prominent matter on which the contention rested—*i.e.*, the favouring of brick and terra-cotta "fireproofing" in preference to concrete—entirely discounted the good features of the suggested enactment.

We are glad to see that the efforts of the brick and terra-cotta industry to thwart the advance of reinforced concrete have again met with a well-merited rebuff.

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An interesting development of this controversy has been the announcement that the Mayor of New York intends to authorise the arrangement of a series of independent tests to determine the value or defects of various so-called fire-resisting materials. Although it is unlikely that anything very novel will be arrived at in these additional investigations they will probably have the advantage of again demonstrating the relative value of different materials under absolutely identical conditions.

We look forward to the results of these investigations, and trust that they will be as impartially conducted as they would be in this country.

THE MAYOR OF NEW YORK ON CONCRETE.

Having regard to the manner in which everything emanating from New York in the way of building regulations is quoted and misquoted in Europe to suit the purposes of different interests, we think it may be of value to quote verbatim the views expressed by the Mayor of New York as to concrete and reinforced concrete when giving his reasons for refusing to sanction the code put before him by the Board of Aldermen of that city. These reasons, coming from an officer thoroughly conversant with the building problem of his city, make interesting reading.

The following are extracts from the Mayor's remarks :—

HEIGHT OF REINFORCED CONCRETE BUILDINGS.

Sub-division 11 of Section 17 of the proposed code limits the height of reinforced concrete buildings to 85 ft. I understand that the board of fire underwriters at first considered 85 ft. as a safe limit, but later decided that 100 ft. would be a reasonable limitation.

Professor Burr, appearing as the chairman of a committee and as a member of the American Society of Civil Engineers, argued before me that there should be no limitation whatsoever on reinforced concrete construction, and pointed out the fact that there were several buildings in this city much higher than 100 ft., which had proved most successful, notwithstanding severe strains, such as the reciprocating action of printing presses.

May I further suggest to your honourable board that you again take up the limitation as to height of reinforced concrete buildings, and consider the arguments of the board of fire underwriters and Professor Burr?

Sections 116 and 117 of the code contain the provisions in regard to hollow tile, cinder-concrete and other fireproofing material.

"CINDER CONCRETE."

If the objections which were offered to the use of the cinder-concrete are valid, it may be questioned whether the use of this material should be permitted at all. If, on the other hand, the claims put forward by the advocates of this material are well founded, Sections 116 and 117 of the proposed code may place unwarrantable restrictions upon its use and unnecessarily increase its cost. The use of cinder-concrete has developed since the enactment of the present code, but there seems ample evidence that it has been used with very satisfactory results in this city when a building has been erected by skilled workmen under careful and intelligent supervision. Whether or not it should be freely admitted on a parity with other methods of construction is a question that can only be decided after more extensive experiments conducted under impartial supervision.

It developed at the hearings before me that no stress tables of this form of construction exist, except those prepared by interested parties, and that no experiments have been made at all to determine the percentage of unburned coal that can be safely allowed in cinder-concrete when used as fireproofing.

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FIRE TESTS.

I have asked Mr. Lewis, chief engineer of the board of estimate and apportionment, to conduct experiments and prepare for you: (1) accurate stress tables; (2) data showing what is a dangerous percentage of unburned coal in cinder-concrete, so that your honourable board may have before it information which will enable you to frame suitable legislation in reference to this form of construction. At all of these experiments I have directed Mr. Lewis to permit representatives both of the cinder-concrete companies and of their opponents, the hollow tile companies, to be present.

Bearing upon the attitude of the Board of Aldermen, which has been adverse to concrete, but which attitude has never been properly and technically explained by them, we think it advisable to give summaries of evidence that was laid before that Board by two leading authorities on the subject—namely, by Professor Ira H. Woolson, of the Columbia University, whose testing laboratory is organised much on the lines of that of the British Fire Prevention Committee here, and the evidence of Professor Norton, of Boston, U.S.A., whose wide experience as the leading technical adviser of the Boston Mutual Insurance Companies is recognised not only in the United States but practically throughout the civilised world:—

PROFESSOR IRA WOOLSON'S VIEWS.

The proposed code is so framed as to exclude the use of cinder-concrete in building construction, and very largely prohibits the use of stone-concrete, due to specifications of weight and height of buildings, etc.

As a result of my years of experience in testing these materials (as well as others), I am positive these restrictions are wrong and unjust.

Well proportioned and well placed concrete is a most excellent fire-resisting material, and in my judgment a first-class cinder-concrete, properly proportioned of cement, sand and good furnace cinders, is the very best fire-resisting material.

FIRE TESTS.

There have been made in this city and vicinity in the past ten years twenty-five fire tests upon full-size floors of reinforced stone-concrete construction. Eighteen of these, or 72 per cent., were successful. There have also been thirty-nine similar tests upon cinder-concrete construction, and thirty-three of them, or 85 per cent., were successful.

I presume that the importance of those tests is not fully appreciated until you take into account the severity of the tests.

The test at the present time in this city requires that such materials shall stand a fire of four hours at an average temperature of 1,700 degrees Fahr., and water shall be applied for ten minutes against the red-hot structure.

That is a very severe test. I do not think it is too severe, because we get plenty of material that will stand it. Nevertheless, it is a very severe test, and when any kind of construction will pass through that fire, and that application of water, and then when fully cooled will stand a load of 600 lb. per sq. ft., it is a very excellent material.

Eighty-five per cent. of the cinder-concrete which I spoke of passed that specification, and they were not all 1-2-4; some of them were 1 cement, 2 sand, and 5 cinders, and some were 1 cement, 1 sand, and 6 cinders; and even as low as 1 cement and 8 cinders—about as bad a thing as ought to be allowed to go into a building, even if used for filling in floor construction. But, strange to say, I have a record of two tests where a 4- and 5-ft. slab passed that specification or test. So it shows it is a good material.

Where very heavy loads are not required on floors, good cinder-concrete makes a light, economical and thoroughly fire-proof construction, and it is unjust to the public and to builders to prohibit its use.

I would like to call attention to another test, conducted in 1903 in this city, in the Butterick building, a 15-storey manufacturing building downtown, which you all know.

I had occasion, on account of some controversy, to go into that building after the roof was practically on and constructed a test house running from the fifth floor to the sixth floor, knocking holes in the walls and using them as chimneys to carry the

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smoke to the outside. We built a fire in that building underneath one of the main girders and the cinder-concrete floor and kept it burning for 2¼ hours, the temperature varying from 1,000 to over 2,000 degrees. There was no injury whatever to the floor or to the beams. They plastered them and went on with the building, and it is as good to-day as it ever was.

"CINDER CONCRETE."

I doubt if such a test was ever made before, and yet that is the cinder-concrete which you have condemned as a fire-resisting material.

I wish it distinctly understood that I mean a good cinder-concrete composed of Portland cement, sand and well-burned hard-coal boiler cinders, in the proportions of about 1-2-5. Such a combination, with sufficient water to make a soft, wet mixture, properly tamped in place, will make a dense, tough, fire-protecting material that can be depended upon to resist fire every time.

The claim is often made that cinder-concrete is used which is composed of very lean mixtures and very poor cinders, and that the material is therefore no good.

I have no defence to offer for such practice, if it exists. I would condemn the use of such inferior mixtures just as vigorously as I would condemn the use of defective materials of any kind in building. If supervision were not made of contractors who would use such material, they would use all sorts of rotten substitutes for building materials other than concrete.

I think it is entirely in the province and power of this city government to make specifications for good building materials of any kind, and then give the superintendent of buildings sufficient inspectors to see that those specifications are lived up to.

The criticism is also frequently made that cinders contain unburned coal that will burn when the concrete is subjected to fire and cause the concrete to disintegrate. I used to believe this myself, but experience has taught me that hard-coal boiler cinders may carry a relatively high per cent. of unburned coal and still not imperil the fire-resisting qualities of the concrete which contains them. The mistake is often made of classing as coal all the black particles present in cinders. Probably one-half or more of such black particles are black slate and not coal.

PROFESSOR CHARLES L. NORTON'S VIEWS.

Concrete is the best fire-proof material, if it is under the structural work, and I will say that of the two I consider cinder-concrete to be much the best.

I have test houses that have been used over and over again—built of cinder-concrete. They have been burned and soused with water, and they have stood the test.

Brick used for buildings is a thing of the past. But the concrete-cinder is here, and it is a good thing.

If you heat concrete the heat goes very deliberately through the concrete. It is a poor conductor of heat; consequently, you must dry out the chemical of the concrete, which takes a great deal of time—a thing which, in the modern construction and with your fire department which can get to the scene quickly, is a considerable factor.

We burn these test houses 10 or 12 hours sometimes, and in any of your buildings here, a fire of 10 or 12 hours' duration in any portion of any building will be a very rare thing.

If I desired to use any material of the concrete type, for instance, or of any type, to give me the most excellent fire-resisting structure, I should unquestionably use the cinder-concrete—not the arbitrary mixture of 1 to 8, which is undoubtedly bad, but 1-2-5. It may be bad in some instances, but by such a proper proportioning as may be necessary, it will give you an absolutely dense, sound concrete.

In two sections of this code, concrete is conspicuous by its omission in connection with elevator wells and partitions. Since there are reinforced concrete partitions, and column coverings, and so on, it would seem to me a grave omission to allow this code to go on in its present condition without permitting, at least, upon an even basis, the protection of columns and the construction of partitions and elevator enclosures of the most excellent fireproof material of which we know, that is, concrete preferably, to my mind cinder-concrete.

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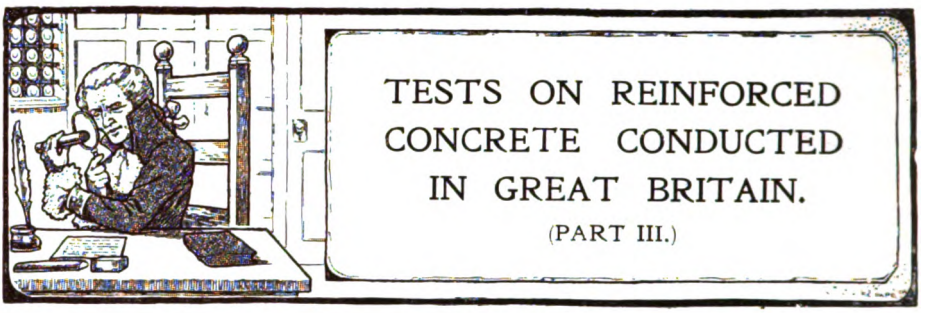

TESTS ON REINFORCED CONCRETE CONDUCTED IN GREAT BRITAIN.

(PART III.)

The absence of systematic testing relating to reinforced concrete has placed this country at a disadvantage in the utilisation of this modern material for structural purposes. Excepting only in regard to fire tests, such investigations as have been conducted have been quite spasmodic in character, and practically always of a purely private nature.

Having regard to the fact that the question of a series of tests being conducted in this country, in a systematic manner, is having the attention of the Institution of Civil Engineers, the Concrete Institute, and other scientific societies, we are presenting particulars, as far as we are able, in chronological order, of such tests as have been conducted in this country from time to time, and this may serve as a useful guide to those who have the arrangements of the tests of the future.

The first and second articles of this series appeared in our May and September numbers respectively. The following particulars of tests are now presented, and further articles will appear from time to time.—ED.

TESTS BY MESSRS. IDRIS & CO.

In 1898 a test was carried out by Idris & Co., Ltd., mineral water manufacturers, on a slab of concrete 7 ft. long by 3 ft. wide by 3 in. thick, made of 4 parts clinker to 1 part Portland cement, with expanded metal of 3-in. mesh, ¼ by ⅜-in. strands, embedded on the underside, supported on timbers giving a clear span of 5 ft. The distribution of the load was applied by means of bricks, which naturally arched themselves, so that the total load was not properly distributed upon the slab. The bricks were piled to a great height, so that a total load of 10 tons or 13 cwt. per sq. ft. was sustained. The deflection is not recorded, nor the crushing strength of the concrete.

TESTS BY MR. J. MANSERGH, M.Inst.C.E.

In 1898, the tests recorded in the table below were carried out on slabs reinforced with expanded metal by Mr. J. Mansergh, M.Inst.C.E., Engineer-in-Chief of the New Birmingham Water Supply. Here, again, the resistances of the materials were not separately ascertained, but the expanded metal may be taken as having approximately the same tensile strength as in the tests carried out by Messrs. Fowler & Baker. The concrete was composed of 4 broken rock (¾-in. gauge) and sand to 1 Portland cement.

TABLE VIII.—EXPANDED METAL TESTS BY MR. JAS. MANSERGH, M.Inst.C.E.

	C	D	A	B
Construction tested	Concrete slab	Concrete slab	Plain concrete slab	Plain concrete slab
Size and dimensions	7′ 6″ × 4′ × 6″ thick	7′ 6″ × 4′ × 6″ thick	7′ 6″ × 4′ × 6″ thick	7′ 6″ × 4′ × 6″ thick
Clear span	6′ 9″	6′ 9″	6′ 9″	6′ 9″
Size and Details and area or percentage of reinforcement	3″ mesh, ¼″ × 3/16″ strands	3″ mesh, ¼″ × 3/16″ strands	None	None
Age	88 to 89 days	88 to 89 days	88 to 89 days	88 to 89 days
Superincumbent load applied	Uniformly	Irregularly	Uniformly	Irregularly
Deflection at centre	½″	¾″	Not observed	Not observed
Total breaking load	26 tons 13¼ cwts.	22 tons 16¾ cwts.	5 tons 12 cwts.	6 tons 13¼ cwts.
Breaking load, cwts. per sq. ft.	19.75	16.92	4.11	4.935

On September 19th and 20th, 1899, some tests on slabs reinforced with expanded metal were conducted by a joint committee of the Northern Architectural Association, the Gateshead and Tyne District Master Builders' Association, and the Council of the Building Trades Exchange. Twelve slabs were set up on wood centerings and brick piers in the foundry yard of the Gallowgate Ironworks,

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TABLE IX.—EXPANDED METAL AND CONCRETE SLABS, TESTED BY NORTHERN ARCHITECTURAL ASSOCIATION.

	1	2	3	4	5	6	7	8	9	10	11	12
Construction tested	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends	Slabs supported at ends
Size and dimensions	9′×4′	9′×4′	7′ 6″×4′	7′ 6″×4′	9′×4′	9′×4′	9′×4′	6′×4′	6′×4′	6′×4′	7′ 6″×4′	7′ 6″×4′
Clear span	8′ None	8′ No. 10, E.M.	6′ 6″ None	6′ 6″ No. 10, E.M.	8′ None	8′ No. 8, E.M.	5′ None	5′ No. 8, E.M.	5′ None	5′ No. 10, E.M.	6′ 5″ None	6′ 6″ No 8, E.M.
Size and details and area or percentage of reinforcement												
Date when made	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899	July 20 and 24, 1899
Date when tested	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899	Sept. 19 and 20, 1899
Age	61 days	61 days	61 days	61 days	61 days	61 days	61 days	61 days	61 days	61 days	61 days	61 days
Deflection	—	About ⅛″	—	⅛″	—	—	—	—	—	Slight	—	—
Total breaking load	9 cwt.	237 cwt. 4 qrs. 14 lb.	22 cwt. 2 qrs. 18 lb.	Unbroken	Not recorded	96 cwt. 1 qr. 17 lb.	124 cwt. 2 qrs. 20 lb.	213 cwt. 3 qrs. 8 lb.	10 cwt. 3 qrs. 10 lb.	Unbroken	17 cwt. 1 qr. 25 lb.	113 cwt. 22 lb.
Remarks	Broke before test began, 2 men and 6 pigs of C.I. being on it—i.e., about 9 cwt.	Cracked at 220 cwt. Deflection ½″ at 175 cwt., and 1″ at 75 cwt.	—	—	Broke accidentally	—				—	—	—

belonging to Henry Walker & Sons, Ltd., on July 20th and 24th, the centerings being removed on August 16th. The concrete was gauged 5 to 1 for the 5-in. slabs, and 3 to 1 for the 3-in. slabs. The cement was fine enough to pass an ordinary gauge, 2,500 meshes to the sq. in., and the concrete for the 5-in. slabs was composed of 4 parts clean washed gravel, to pass a 2-in. gauge, 1 part clean sand, and 1 part Portland cement. The concrete for the 3-in. slabs was composed of 2 parts clean washed gravel, to 1-in. gauge, 1 part clean sand, and 1 part Portland cement. The cement was procured from a merchant in the ordinary way, and when tested gave no residue through the 50 sieve, and only 2 per cent. through the 70 sieve. It weighed 94 lb. per strike bushel. The slabs when cast remained exposed in the open to continuous hot sun, which had "spider's webbed" the surface of the cement. No. 4 slab was partly protected from the sun. It may be stated generally that there was only a slight deflection before breaking, the fracture of the expanded metal was clean, and of crystalised appearance, the strands of steel having come close together under the load, the diamonds being considerably elongated. The age of the slabs when tested was 61 days; whereas, the slabs tested by Fowler and Baker, in London, in March, 1896, were 63 and more days old when tested. Also, it may be noted that the cement used in Newcastle was finer ground, and weighed less than that used in the London slabs. The slabs were supported only at the ends, and each end had a 6-in. bearing on the wall. The loading was applied by means of pigs of iron placed so as to cross each other in each layer, this bonding rendering the results inconclusive and misleading, for the arching was naturally very considerable.

In 1903 Messrs. A. T.

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Walmisley, M.Inst.C.E., J. P. Allen, and Andrew Hope Morton, A.M.Inst.C.E., carried out a test on a concrete slab reinforced with expanded metal, on January 20th, at Messrs. Connal's Pig Iron Stores, off Paisley Road, W., Glasgow. The slab was 7 in. thick and reinforced with a layer at the bottom of No. 10 3-in. mesh expanded metal, the strands of which were ¾ by $\frac{3}{16}$ in. (bare). The slab was constructed on August 2nd, 1902, and its temporary centering was struck on September 2nd, 1902. It measured 15 ft. 6 in. by 15 ft. 6 in., and had a bearing of 6 in. on all four sides, so that the unsupported area of the slab was 15 ft. by 15 ft. The slab was supported upon dwarf walls 3 ft. in height. The whole of the details are shown in *Fig.* 9. The load was applied by pigs of iron carefully laid on the unsupported area of the slab—*i.e.*, clear of the supporting walls. The ultimate load sustained was 56 tons 11 cwt. The fractures radiated from the centre to the angles of the square. It was made of concrete composed of 1 part Portland cement to 2½ parts broken brick to pass a ¾ in. mesh sieve, and 1½ parts clean, sharp sand, all obtained in the neighbourhood of the test in the ordinary way. The slab had been previously loaded with an evenly distributed load of 3 cwt. per foot super on November 12th, 1902, this load remaining on the slab until January 20th.

On February 5th, 1899, a fire test was conducted by the British Fire Prevention Committee on a floor reinforced with expanded metal, of which details and particulars have already been published.

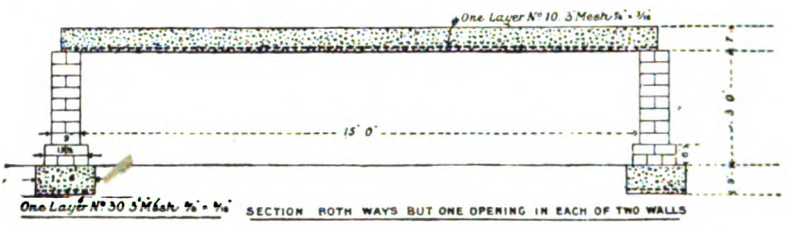


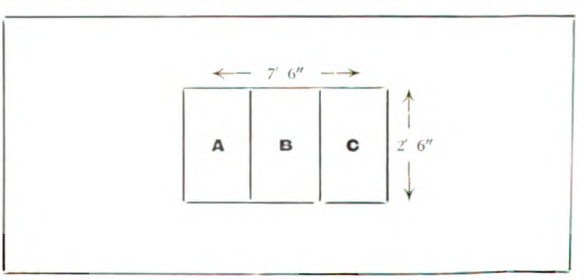
FIG. 9. SLAB REINFORCED WITH EXPANDED METAL, TESTED AT GLASGOW, 1903.

In 1896 a test was conducted on arches reinforced with expanded metal, undertaken in connection with the flooring designs of the New Brighton Tower, and the first test was on a long span floor arch constructed of channel irons curved to form arches, set between main girders 12 ft. apart, the ends of which were held by plates. The channels were about 4 ft. apart, the arches being filled with concrete, whilst across them was placed the expanded metal. On this 2 in. of concrete was placed, making a flat floor between the curved channels to the above thickness. The floor was 12 ft. long on the arch and 4 ft. wide. The breaking strain was tested by means of lead ingots weighing 100 lb. each, which were carefully piled up in separate stacks covering the whole of the floor area The breaking load was 17 cwt. per sq. ft. At this point the tie rods, which were holding the main girders together, broke, after which the deflection from the centre of the main girders allowed the main arches to sink, and the floor gradually settled. The second test was conducted with an arch on the "Monier" system, in which expanded metal was used in place of the ordinary rods. The arch was of concrete, 3 in. thick at the crown, 16 in. at the bottom, with a length of 12 ft. and a width of 4 ft. The expanded metal was laid on the curved centering, and had a rise of 13 in in 12 ft., and the concrete was placed over the metal. The load was applied with lead ingots, as in the first test. The arch did not break until 12 cwts. per sq. ft. had been placed upon it.

TESTS BY WILKINSON & CO., LTD., OF FULHAM.

We give illustrations and particulars of two floor tests conducted by Messrs. W. B Wilkinson & Co, Ltd., of Fulham, London, S.W., in 1905 and 1906.

On April 12th, 1905 (a very wet day), a slab of reinforced concrete, 12 ft. by 9 ft., with a clear span of 11 ft. 6 in. by 8 ft. 3 in., was tested. The slab was 5 in. thick (4 in. of crushed brick concrete and 1 in. granolithic 2½ to 1). The reinforcement consisted of ¾-in. round rods placed at 12-in. centres across 9 ft. and ¾-in. round rods at 18-in. centres as tie rods the reverse way. The total weight of the reinforcement was equal to 15·55 lb. per sq. yd. The age of the slab was two months. The load was applied in the centre, and consisted of 300 pigs of lead weighing 15 tons 3 cwt., as shown in the sketch plan :—



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The pigs were stacked in three piles, five in a row each way. The centre pile (*b*) consisted of 24 rows high—120 pigs, and piles (*a*) and (*c*) each had 18 rows—90 pigs each. Reckoning the load in centre as being equal to twice that load distributed, this is equal to $6\frac{1}{3}$ cwt. per ft. super of the clear span.

There was no deflection whatever until 11 tons 8 cwt. had been put on (*i.e.*, the 24 rows in centre and 11 rows on *a* and *c*), when a crack appeared on the underside, and there was a deflection of barely $\frac{1}{8}$ in. in centre. Where the full load was applied, the full deflection at centre was $\frac{3}{8}$ in., but this was largely due to the fact that the two joists supporting the ends of slab had also deflected $\frac{1}{4}$ in. These joists were 5 in. by 3 in. by 11 lb., and the concrete rested 3 in. on them, the joists being braced by two bolts to prevent lateral movement.

FIG. 10. TEST AT WILKINSON'S YARD IN 1905.

Twenty-four hours after the load had been removed, the floor went back to within $\frac{3}{32}$ in. of its original level. There were three or four small radiating cracks on the underside, but no injury whatever to the upper surface. The slab is still in existence, and forms a roof to an open store in Messrs. Wilkinson's yard. This slab was tested in the presence of two of the London and South Western Railway company's engineers, and the illustration (*Fig.* 10) shows the manner in which the loading was applied and the apparatus for testing the levels.

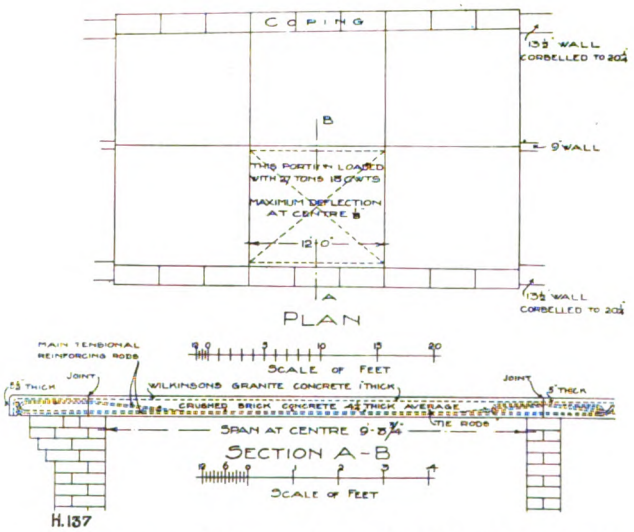

FIG. 11. TEST ON A WILKINSON SLAB AT WATERLOO STATION IN 1906.

On May 29th, 1906, a similar test was carried out at Waterloo Station by the engineers of the London and South-Western Railway, on a slab forming part of a portion of a platform erected for the purpose, and since removed for the permanent platforms constructed by Messrs. Wilkinson & Co. The total measurement of the slab was 36 ft. by 23 ft. $7\frac{1}{2}$ in., with $13\frac{1}{2}$ in. walls corbelled out to 1 ft. 9 in. at outer edges, with an overhanging coping $5\frac{1}{4}$ in., and one central wall 9 in. thick, with open ends. The slab was made up of six sections, each about 12 ft. by 10 ft. $\frac{1}{4}$ in., with nine slabs of coping on each of the two edges 4 ft. long by 1 ft. 9 in. wide. The whole was bonded together as regards the reinforcement, but with plain butt sectional joints in the concrete. The slab averaged $5\frac{1}{4}$ in. thick (*i.e.*, $5\frac{1}{2}$ in. at edge of coping and 5 in. at centre wall), but the thickness of the slab tested would be rather less than this, owing to the continuous slope from edge of coping. The reinforcement was exactly similar to

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that in the test described above, and the concrete also. The details are shown in *Fig.* 11. One slab was loaded with bricks, which were weighed and put on by the railway company's men, and finally the load on 12 ft. by 9 ft. $3\frac{3}{4}$ in. was 27 tons 18 cwt., or very nearly 5 cwt. per ft. super. The maximum deflection at centre was $\frac{1}{8}$ in., but no cracks whatever appeared on the underside. There was no movement until the load exceeded 4 cwt. per ft. The load was allowed to remain on the slab for 3 weeks, and the deflection did not increase in the slightest degree; but a week after the load was removed, the maximum deflection at centre was only $\frac{1}{16}$ in. The adjoining slabs were not appreciably affected, and the deflection at the centre point, and 1 ft. from the joint of the next slab (*i.e.*, 1 ft. under the load) was only $\frac{1}{16}$ maximum. The slab was the same age as that in the previous test.

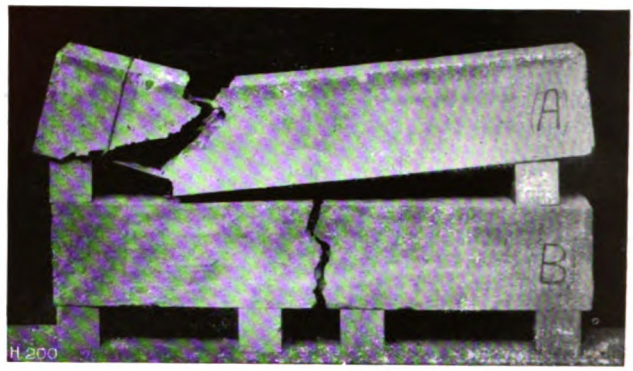

FIG. 12. TEST ON CONCRETE LINTOLS.

FIG. 12*a*.

CHARNOCK TESTS.

The following give particulars of two tests conducted by Mr. G. F. Charnock, Assoc.M.Inst. C.E., Professor of Engineering of the Testing Laboratory of Departmental Engineering, of the City of Bradford Technical College. The tests took place on April 15th, 1908, two concrete lintols being received from Messrs. Joseph Sankey & Sons, Ltd., of Bilston, Staffs. One lintol was of plain concrete and the other was reinforced with patent reinforcements, for which Messrs. Sankey are the agents, and the form of which is illustrated in *Fig.* 12*a*.

Both specimens were composed of 1 part best Portland cement, 3 parts best broken brick, and 1 part clean sharp sand. They were moulded on August 10th, 1907, so that at the date of testing (April 15th, 1908) they were over eight months old.

PROF. CHARNOCK'S TESTS, APRIL 15TH, 1908.

	Dimensions	Span	Sectional Area of Metal	Breaking Load
Plain concrete lintol	5″ wide, 7″ deep	2′ 6″	None.	·54 tons
Concrete lintol reinforced with "Sideolith" expanded metal	5″ wide, 7″ deep	2′ 6″	·25 sq. in.	4·1 tons

RYDE PIER TEST.

A test on a section of a floor slab similar in construction to the new deck to Ryde Pier was conducted by Mr. Percy Tomey, who was then carrying out the work for the London and South-Western and London, Brighton and South Coast Railway Co.'s Joint Committee. In the actual work the deck consisted of compound longitudinal girders and R.S.J. fillers, these being spaced at about 5 ft. centres. The slab of reinforced concrete thereon was designed to carry a safe load of 15 tons per lineal yard of track. The reinforcement consisted of sheets of Richard Johnson, Clapham & Morris's woven wire lattice meshwork, standard section No. 11—*i.e.*, $1\frac{1}{2}$ in. by 3 in. mesh, No. 6 by 11 G. wires, in lengths of 101 ft., the reinforcement being continuous over 20 supports. The ratio of reinforcement to concrete in sectional area was 1 : 288, or about ·33 per cent.

Particulars of Test.—An official test was held in the London and South-Western yard at Wimbledon on October 4th, 8th, and 9th.

Fig. 13 shows the longitudinal and cross section of the slab as tested. The concrete used in construction of the slab was identical to that being used in the actual work, ballast being sent up from Ryde.

The ballast was passed through a screen to separate the sand and fine material, and the concrete

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was mixed in the proportions of 4 parts stone, 2 parts sand and fine stuff, to 1 part of Portland cement The concrete was laid on August 2nd, 1906, and the centering struck on August 9th, 1906, and the first test load applied on October 4th, 1906.

The load applied was 30 tons distributed over a lin. yd., and the deflection was ¼ in. at the centre of the span.

This load was then removed from off the slab by means of hydraulic jacks, when it was noticed that the slab recovered its flat form.

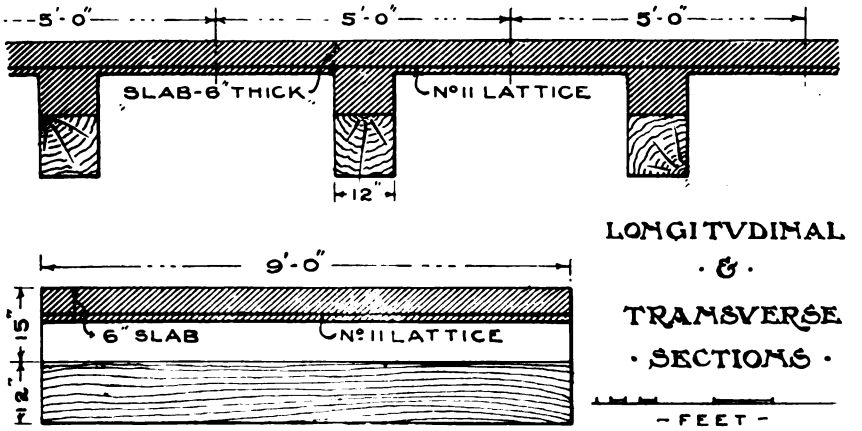

Fig. 13

The two longitudinal timbers and the two cross timbers were then drawn, and the two side haunches were also removed, and the load of 30 tons lowered on to a single timber placed in the centre of the middle bay, when some hair cracks appeared on the under side of the slab near the centre. The load was then increased to 35 tons, when fine shear cracks appeared near the supports, commencing at the bottom of the slab and running at about 45° towards the centre of the slab.

The largest of these cracks measured $\frac{1}{16}$ in. at its widest part, and the deflection of the slab was 1 in. The slab was then loaded with a further 5 tons, when it collapsed. The slab failed in shear, and the reinforcement did not give way at any point, neither did it slip within the concrete.

The concentrated breaking load of 40 tons equals a distributed load of 35½ cwt. per ft. super on the slab, which is equal to a safe working load of practically 9 cwt. per ft. super, with a factor of safety of 4.

HODKIN AND JONES'S TESTS.

In 1905 Messrs. Hodkin & Jones, Ltd., introduced a corrugated bar for reinforcing concrete floors, and in connection therewith tested two floors, one reinforced with ordinary light joists, and

Fig. 14. Tests on Hodkin & Jones' Floors.

Corrugated Bar Floor.
Breaking load, 21 tons 1 cwt. (cracked only).

Ordinary I Joist Floor.
Collapsed at a load of 16 tons 11 cwt.

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the other with their corrugated bars, as also upon these reinforcements alone. The corrugated bars used in both tests were of the same section, weighed 4 lb. per ft. run. The joist section was 3 in. × 1½ in., weighing 4 lb. per lineal ft.

A corrugated bar alone, 13 ft. long and weighing 52 lb., was placed over an opening 12 ft. span, with its ends placed in pierced slots of thin sheet iron to keep the bar vertical, and not clamped down in any way. A weight of 12 cwt. was suspended by a cradle as a point load, the deflection being 1½ in. A 13-ft length of the joist of same weight—namely, 52 lb.—was placed over an exactly similar span, but without end slotted plates, and failed under the load of 12 cwt., its deflection being 10 in. when on the point of collapse.

The floors constructed with these reinforcements were similar, and are shown in *Fig.* 14. They measured 10 ft. by 11 ft., the span between girder beams being 9 ft. The thickness of the concrete was 7 in., and its age when tested 28 days. The bars and joists were spaced alike, 2 ft. apart. The load of bricks, which no doubt arched somewhat, was placed in the centre, covering 8 by 6 ft. The ends of all bars and joists were free. The corrugated bar floor deflected ⅝ in. with a load of 17 tons 1 cwt., while the joist floor deflected ⅝ in. with only 13 tons 17 cwt. The former cracked at 21 tons 1 cwt., while the joist floor collapsed at 16 tons 11 cwt.

A test beam reinforced with a corrugated bar of the same section as the foregoing. The beam was 4 ft. long, and measured 8 in. by 9 in. The test was made by the Sheffield Testing Works, Ltd., Blonk Street, Sheffield. The load was applied by hydraulic pressure at the centre, and the beam broke at 9·18 tons.

Fig. 15 shows a test on a reinforced concrete floor of more usual pattern. It was a facsimile of a heavy steel rolling mill floor constructed by the firm to carry a safe working super load of 20 cwts. per sq. ft., with a factor of safety of 4. The view shows the flooring carrying steel billets of more than double the specified load.

The following are particulars of the construction : Concrete sleeper walls, 12 in. thick, and 9ft. 4 in. centres ; reinforced concrete beams, 10 by 5 in., 4 ft. 2 in. centre to centre ; floor slab, 8 in. thick ; steel reinforcement of plain round bars. The concrete was proportioned 1 : 2 : 4. The test at the right hand of the view was a distributed load—namely, 1,800 cwt. on an area of 72 ft. super. The test on the left hand was conducted at the request of the proprietors, and consisted in placing the load of 980 cwt. in the centre of a bay on an area of 20 ft. super, equal to 49 cwt. per sq. ft. The floor under these loads showed no cracks, nor was there any appreciable deflection. We have not been able to obtain adequate particulars of the reinforcement used nor a drawing showing its arrangement.

Fig 15 Test on Hodkin & Jones's Floor.

(To be continued.)

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The New Western District Post Office, London

The Western District Post Office is a structure that well merits illustration and description in these columns. It has already twice been the subject of articles in this journal, and the present one must thus be looked upon solely as a supplementary one. We feel sure, however, that the three articles, if read together, must serve as a useful contribution to our records of modern structures in which the application of reinforced concrete has played an important part.—ED.

THE Concrete Institute is well advised to arrange for visits to works of technical interest, and if these visits have up to the present all taken place in or near the metropolis, we trust that in due course similar ones will also be arranged in the provinces so as to enable the provincial members to inspect structures of importance in their respective districts. The latest visit of the Institute has been one to the Western District Post Office, which is being erected to the instructions of H.M. Office of Works—*i.e.*, the department to which Sir Henry Tanner, I.S.O., F.R.I.B.A., acts as the principal architect.

REINFORCED CONCRETE SKELETON OF THE BUILDING.

Mr. J. Wager, A.R.I.B.A., the architect of the building, received some sixty members of the Institute on Thursday, October 14th, the party being under the guidance of their Chairman, Mr. Edwin O. Sachs, F.R.S.Ed., and their Honorary Treasurer, Mr. E. P. Wells, J.P. Mr. G. C. Workman, managing director of Messrs. Edmond Coignet, Ltd.—which firm is responsible for the specialist design of the reinforced concrete construction—was also present, accompanied by Mr. Maurice Béhar, the chief engineer to the company, and Mr. William F. King, of Messrs. King & Co., the contractors for the work, also attended.

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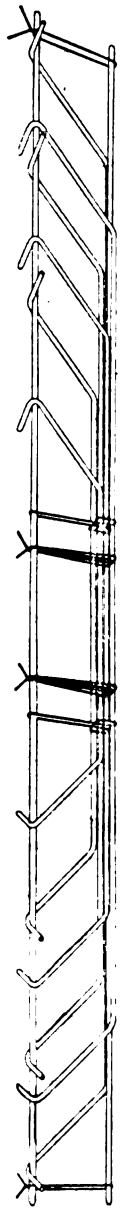
An excellent selection of general drawings and details had been carefully arranged for the members to study, and there were also some useful models, which did much to explain the principle of the reinforcement adopted.



Sketch of Model Illustrating the Coignet System of Design.

It may be remembered that we have dealt with this building in two of our issues, in July, 1908, and May, 1909. Our first article showed the structure in its preliminary stage, and the second included views of the work nearing completion. Thus those two articles, supplemented by the current one, should together serve not only as a most useful history of the structure, but practically give all the more valuable particulars that are of interest to our readers. Further, the three articles show the importance of the building, and also indicate a number of highly interesting features in its design, as well as clearly illustrating the excellence of the workmanship, which has been very much admired and does great credit to the contractors.

In this supplemental article we think we cannot do better than to give extracts from the addresses of Mr. Wager and Mr. Workman on the occasion of the visit of the Concrete Institute, and would mention that both these gentlemen, as well as Mr. King, were thanked for their presence by the Chairman on behalf of the members.

The drawings we present supplement those that have already been illustrated in our columns. The general plan we, however, republish with the view of facilitating reference.

In conclusion, we think we should not only congratulate the Office of Works on this excellent example of the economic application of reinforced concrete, Mr. Wager on the successful accomplishment of his duties as architect to the building, and, lastly, the specialist designers and contractors, who, we have pleasure in announcing, have also just entered into a contract to erect a further Post Office structure for the same department, *i.e.*, the New Money Order Office.

The following are some extracts from Mr. Wager's address to the members of the Institute, his remarks in the main being confined to the history of the building and its general arrangements:—

MR. WAGER'S ADDRESS.

"In bidding you welcome to this building, it is but right to say that whilst I am the architect, I cannot and do not claim to be in any sense the designer of the reinforced concrete carcase which we see, but an architect compelled by force of circumstances, and originally somewhat against my inclinations, to deal with this most useful material. The methods of construction will be explained to you by Mr. Workman, Messrs. Coignet's representative in this country, and Mr. Béhar, their chief engineer.

"The plans were originally got out for an ordinary brick and stone building, or rather shell carried on steel stanchions and girders, somewhat similar to other buildings erected for the Post Office by the Office of Works, and these, of course, gave the general scheme of supports and beams which, when it was decided

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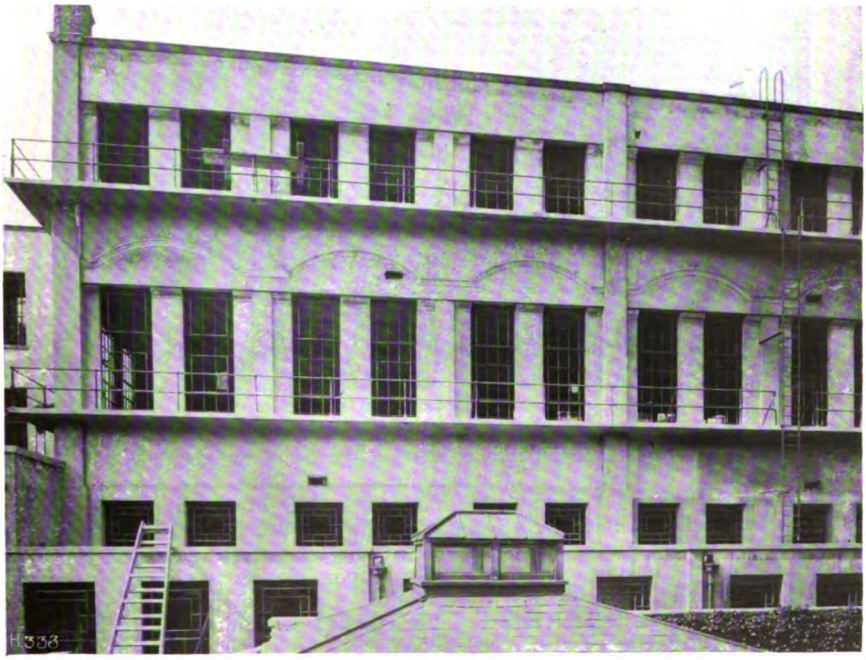
Interior view of one of the Offices.



View of Side Elevation.
WESTERN DISTRICT POST OFFICE.

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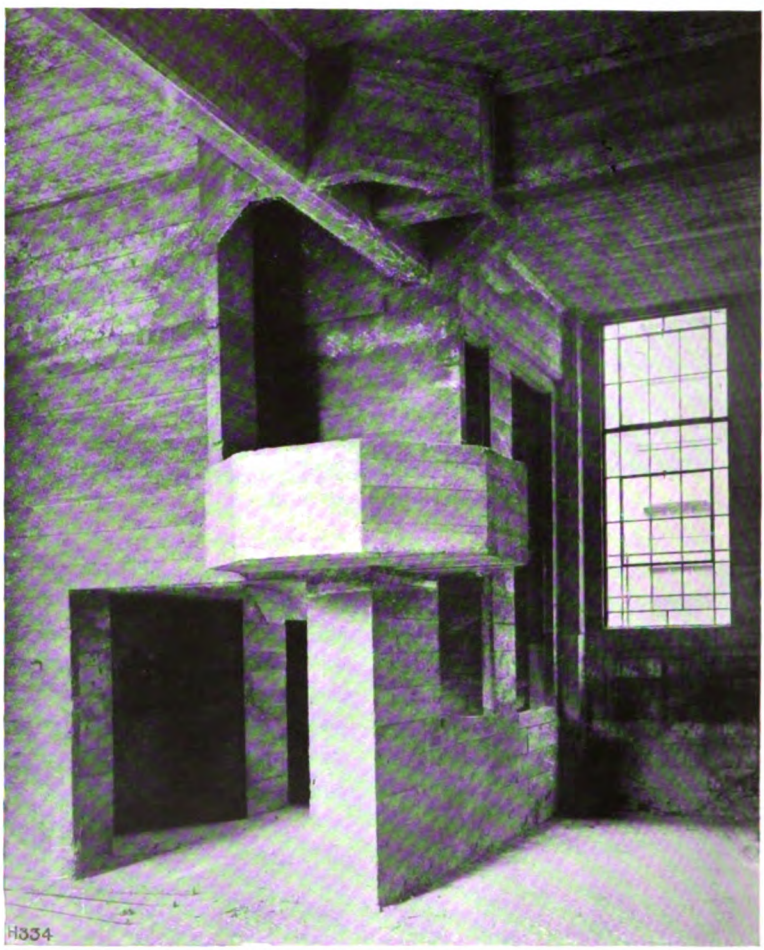
to erect the building in reinforced concrete, were, with a specification, supplied to the firms invited to prepare schemes and tenders—viz., Messrs. Edmond Coignet, Ltd., The Considère Construction Co., Ltd., The Continuous Concrete Construction Co., The Expanded Metal Co., Ltd., Mouchel and Partners, Ltd., The Patent Indented Steel Bar Co., Ltd., Potter & Co., Stuart's Granolithic Co., The Trussed Concrete Steel Co., Ltd., and Mr. Percy Young.



WESTERN DISTRICT POST OFFICE
View of Inspection Gallery.

"When tenders were received they were referred to our member, Mr. William Dunn, F.R.I.B.A., to examine and report upon, and ultimately, after some adjustments to meet Mr. Dunn's recommendations, the tender of Messrs. William King & Sons (licensees of Messrs. Edmond Coignet, Ltd.) was accepted.

"We had scarcely started when our neighbours began to raise objections to some of the arrangements, and to meet these as far as possible the whole of the front block had to be re-planned to give an increased loading yard, and though this had a detrimental effect upon the street elevation, I am inclined to think the arrangements will be better for the Post Office work.

"You will, I think, see the general arrangements from the plans: to the south the entrance for the general public to the large public office (48 ft. by 37 ft.) on ground floor and to the offices of the Postmaster and of the clerical staff; at the north end an

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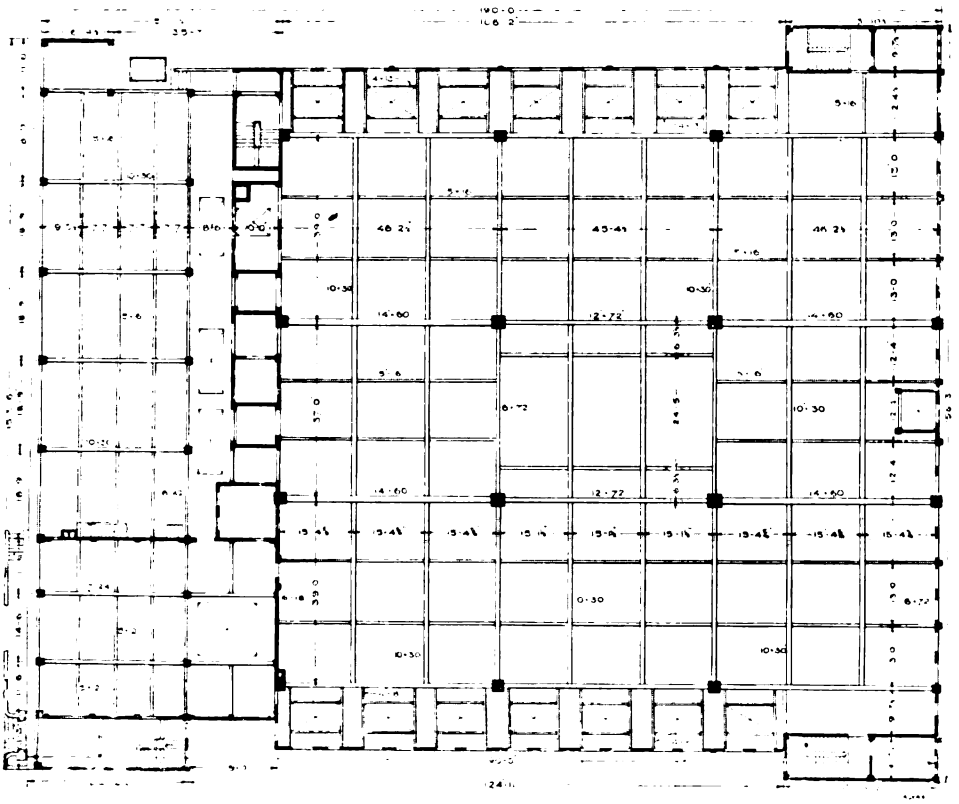
entrance for the sorting staff, postmen, etc., with slope for handcarts and cycles to basement; between these the large loading yard (93 ft. long) and platform, with two lifts; the whole of the back block on ground floor is the lower sorting office (141 ft. by 136 ft.), lighted by windows all round and a large central skylight.

"Above this is the postmen's sorting office (136 ft. by 115 ft. extreme), and on the second floor the whole of the retiring rooms, library, kitchen, dining-room, instrument-room, sanitary offices, and lavatories. The roof is but a temporary one, as it is intended eventually to add a third storey, for which the floor and beams are already constructed.



WESTERN DISTRICT POST OFFICE.
Plan of the ground floor level

"There is a very large basement for storage of baskets, etc., and at times of great pressure portions will be used for sorting and other work, but not normally.

"There is a large boiler-room, battery-room, and other offices in the basement."

Mr. G. C. Workman, C.E. (of Messrs Edmond Coignet, Ltd.), thereupon gave a detailed technical description of the reinforced concrete structure, preceding his remarks with a very clear and concise explanation of the system of design—*i.e.*, the Coignet System—here applied.

Having dealt with the structure in previous issues of this journal (July, 1908, and May, 1909), we will only print extracts from Mr. Workman's description of the building, but his explanation of the system of design applied is such a useful summary of the principles involved that we give it verbatim. The description was illustrated by some excellent models.

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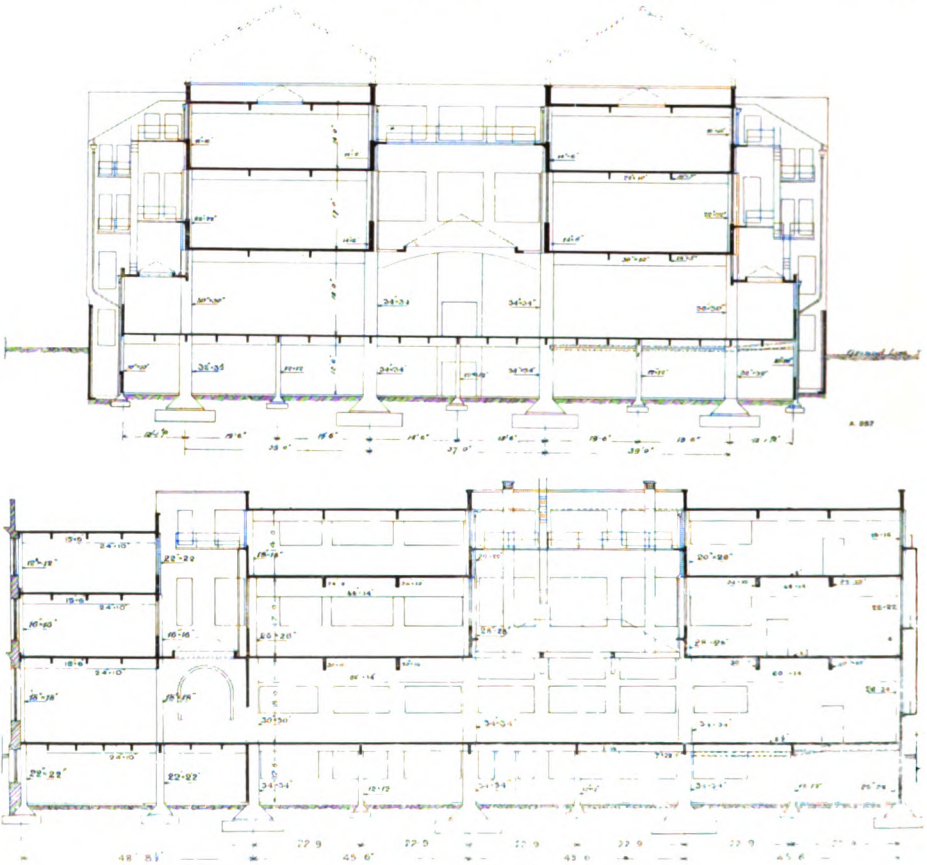
THE COIGNET SYSTEM OF DESIGN.

The Pillars.—Dealing with the question of pillars first, the model which is exhibited shows you very clearly how the steel armouring is arranged inside the concrete. You will also notice the arrangement of the bars to form footings, in order to spread the loads on to the ordinary concrete blocks, which are first placed upon the ground.

The Beams.—Concerning the beams, you have here two steel frameworks showing the manner in which the armouring is arranged inside the concrete (see page 400). In the first case, you will notice that the tension in the beam is taken up by the lower bars and connected to the upper part of the concrete or slab of the beam by



WESTERN DISTRICT POST OFFICE.
Transverse and longitudinal section.

stirrups, which are hooked over the longitudinal top bar, thereby forming a perfect bond between the tensional and compressed areas of the beam.

The stirrups, which are meant to resist the shear also, are, as you will notice, spaced closer towards the points of support, on account of the fact that the shearing stresses are higher at these points and gradually grow less towards the centre. You will also notice that these steel frameworks can be very easily put together, and are connected to the principal bars by means of annealed wire, to prevent them getting out of position.

This arrangement enables these frameworks to be made beforehand and to be placed inside the moulds without any danger of changing the relative position of the various bars, which is a very important thing.

The other framework, which is here shown, is based upon the same principle as

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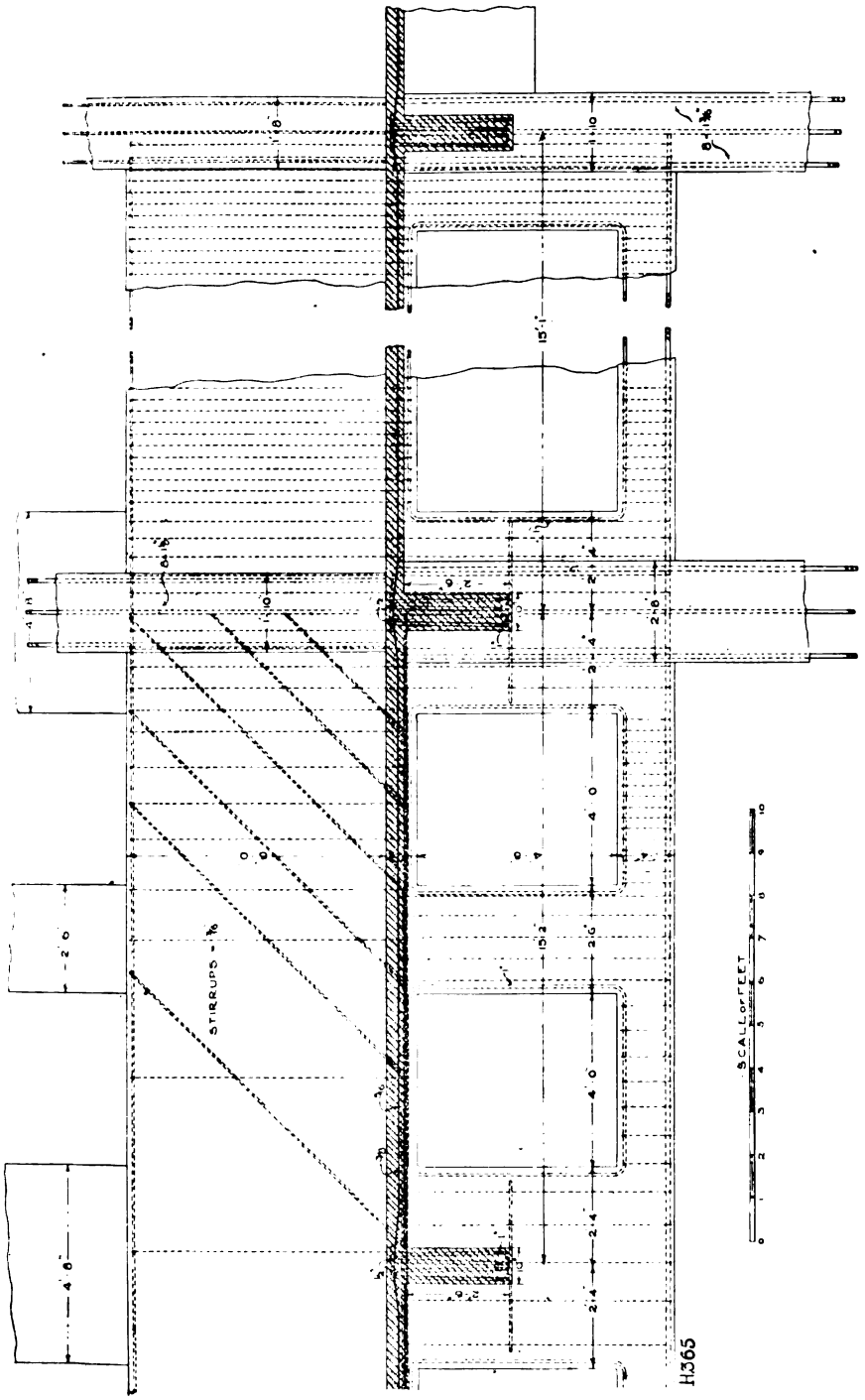

WESTERN DISTRICT POST OFFICE.
Details at first floor level.

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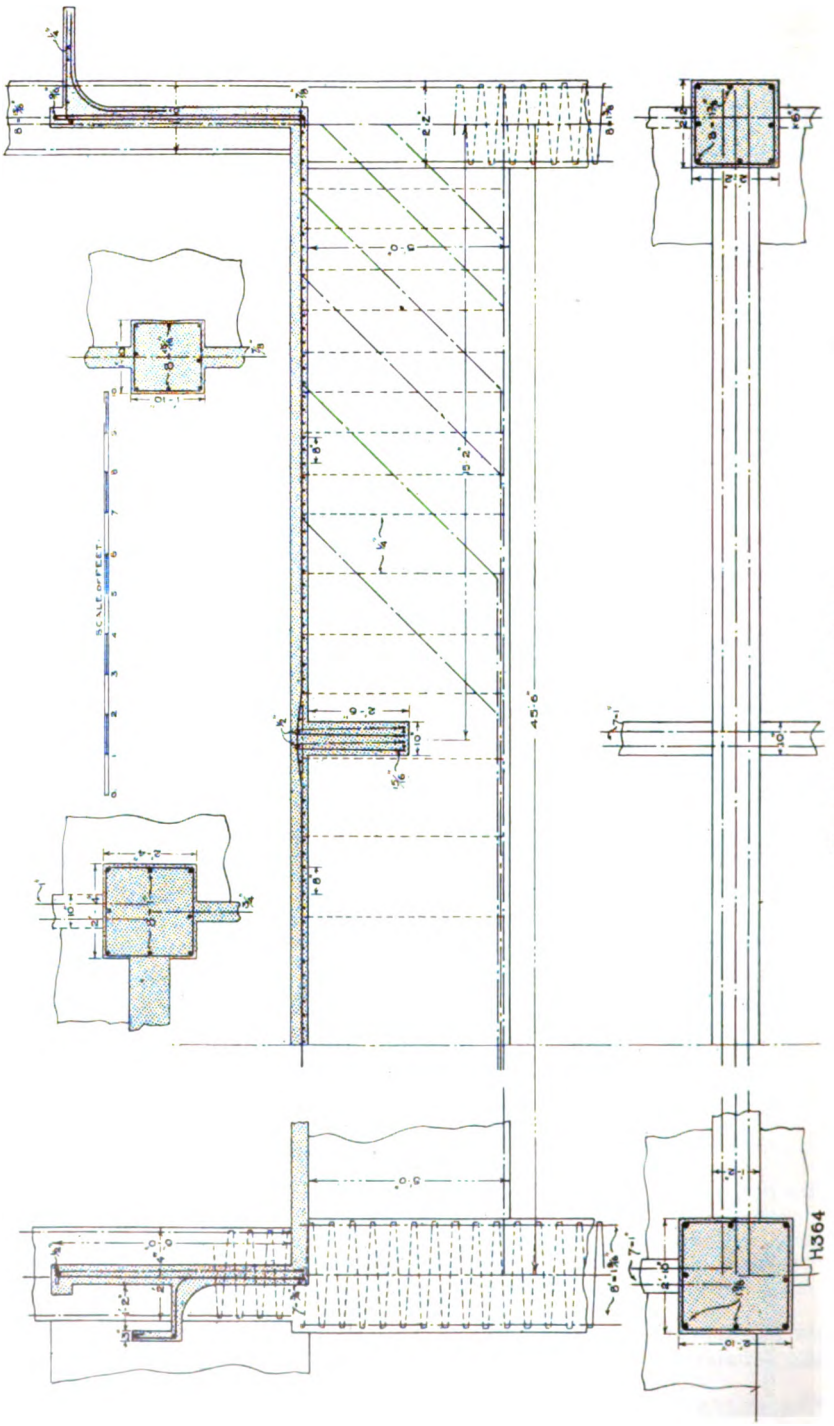

Western District Post Office
Details at first floor level.

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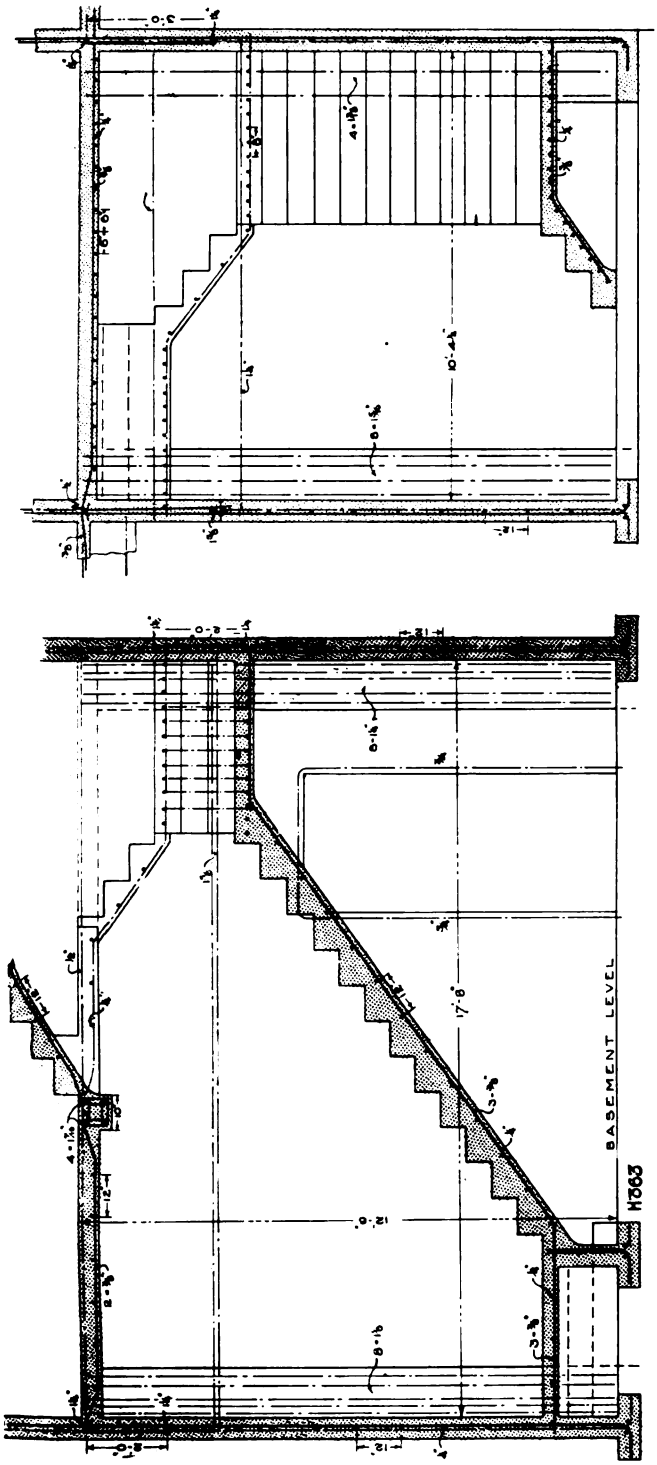

WESTERN DISTRICT POST OFFICE.
Details of the south-west staircase from basement to ground floor level.

the first one, but instead of having one or two bars of large section in the tensional part, there are smaller bars arranged in a group, and these, as you will see, are of varying lengths, having their ends bent up at an angle of 45 degrees, and hooked over the top bars in order to resist shearing stresses.

These bent portions are spaced gradually farther apart towards the centre and they are also intended to resist shearing stresses.

We call the beams formed by means of this framework "beams of equal resistance," because you will notice that the sectional area is greater towards the centre, where the maximum bending moments occur and gradually diminishes towards the points of support where the bending moments grow less.

On the other hand, as the shearing stresses increase towards the points of support we use the steel by bending it upwards to resist these stresses. The resistance is, therefore, always calculated to be sufficient to meet the stresses in an equal manner.

I wish to point out also that the negative moments which occur in the top portion of two adjoining beams are taken up by what

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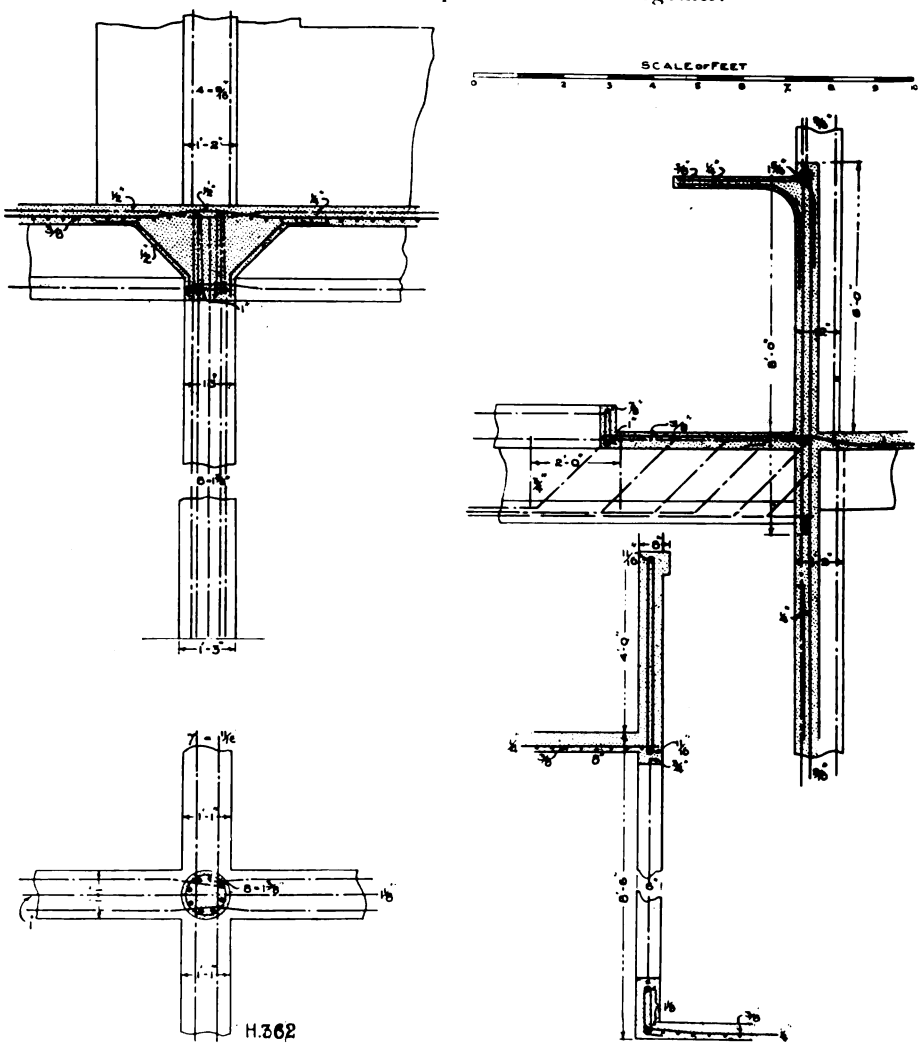
we call joint bars. This is simply a small length of bar which is placed in the upper portion of two consecutive beams.

In practice, we have found it advisable to use the equal resistance system for large beams and the stirrup system for smaller beams or lintels, and also in cases where beams are very high as compared to their width. In this case, the stirrups are better suited, in our estimation, to reinforce the concrete in every part.

It will be noticed that in the last described system there are also a few stirrups. These are only meant, as a rule, to keep the framework together.



WESTERN DISTRICT POST OFFICE.
Details from front block, first floor level.

The Slabs.—Concerning the slabs, rectangular slabs are generally composed of principal bars in the lower portion of the concrete, and distributing bars on the top of these, and running at right angles to them. The square slabs are composed of principal bars running in both directions at right angles to each other, and also placed in the lower portion of the concrete.

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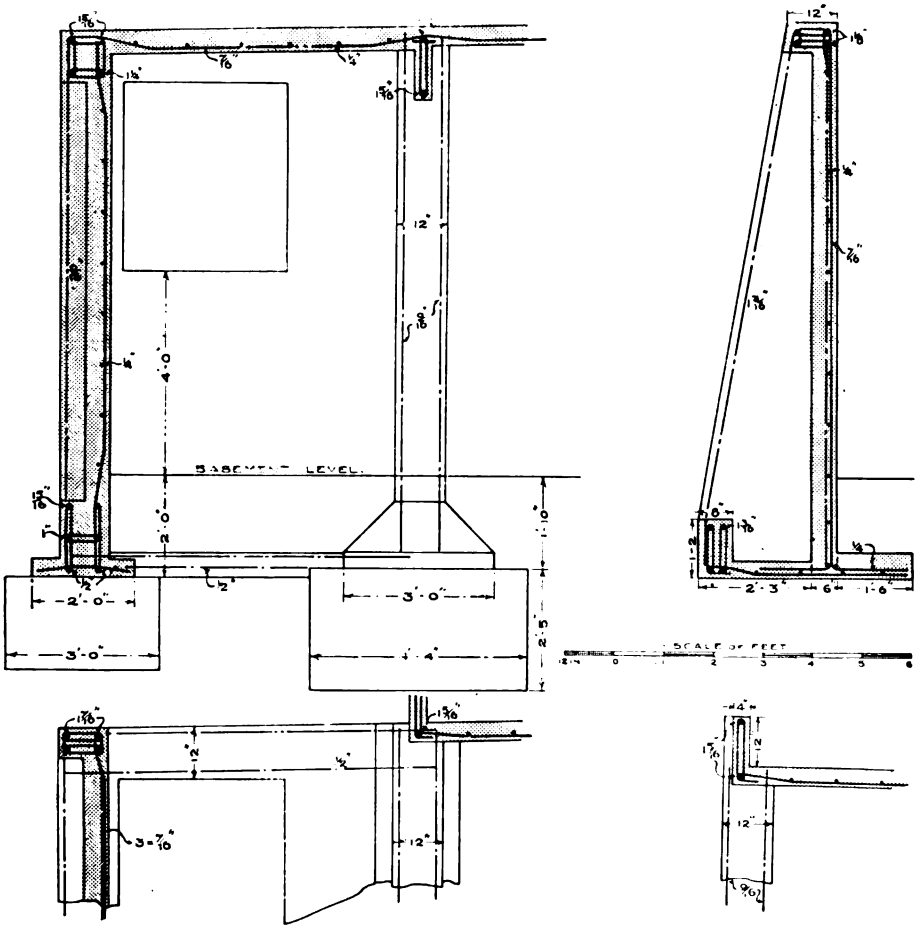
The Walls.—The walls or panels are formed of a meshwork of small bars of about ¼ in. diameter, placed generally in the centre of such panels.

The Materials.—In preparing the design on this system the very best of materials were assumed. The bars for making the frameworks were thus ordinary mild steel, provided by Messrs. The Earl of Dudley's Roundoak Works, Ltd., of Brierley Hill, Staffs.

The concrete, the mixture of which was approximately 1 to 5, was composed of the "Ferrocrete" brand of Portland cement, sand and small ballast. This brand of cement, which has the advantage of exceptionally fine grinding, was obtained from the Associated Portland Cement Manufacturers (1900) Ltd., in special small sacks.



WESTERN DISTRICT POST OFFICE.
Details of front retaining wall.

NOTES ON THE REINFORCED CONCRETE STRUCTURE.

This building as indicated by Mr. Wager comprises a ground floor, first floor, second floor, and roof.

Loads Provided for.—The superload of the ground floor is 1 cwt. per sq. ft., tested to a load of 1½ cwt.

The first floor is calculated to support the same load.

The second floor and roof are calculated for a superload of ¾ cwt. per sq. ft.

The loading platform for vans is calculated for a load of 4 cwt. per sq. ft., and it has been tested to 6 cwt. per sq. ft.

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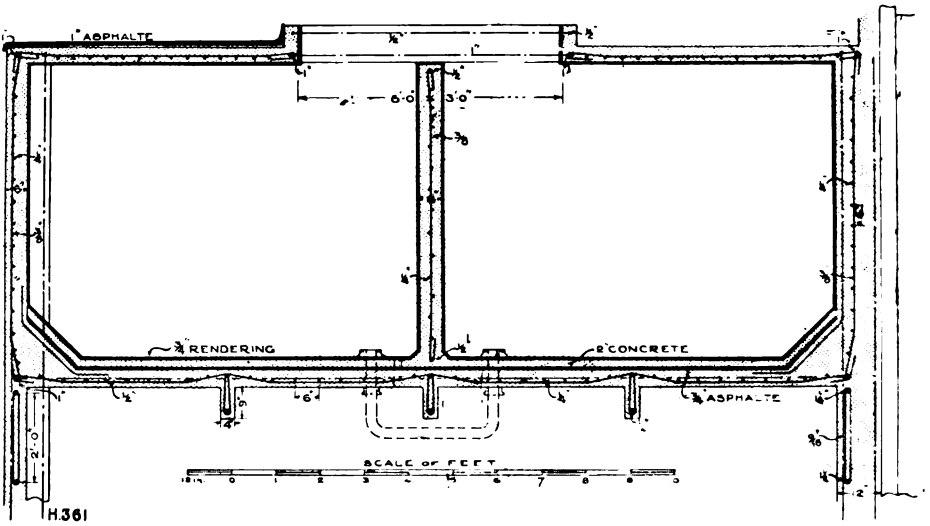
The Sorting Office and the 115-ft. Beams.—The most important portion, and also the most interesting one, is the large sorting office, which measures approximately 141 ft. in width between the walls and 137 ft. in depth, also between the walls.

The four central pillars are, therefore, supporting beams which have a span of 45 ft. in one direction and 39 ft. in the other. This means that the concentrated loads upon these pillars are very considerable, and it is for this reason and also to give more stability to the structure that it has been found advisable to make them of a large section.

We have, therefore, areas of flooring between principal beams which measure approximately 1,800 sq. ft. As you will notice, the area of flooring in each corner of the sorting office is composed of principal and secondary beams. The remaining area of flooring between the central pillars had to be suspended to upper beams forming at the same time the inner walls of the courtyard. This arrangement is to give more light to the sorting office.

It will easily be understood that the problem which had to be solved was by no means an easy one, on account of the considerable spans and loads which had to be



WESTERN DISTRICT POST OFFICE.
Details of Tank.

supported. The two suspended beams which are running throughout the width of the floor without any apparent support, are, therefore, in reality supported by upper beams, as otherwise the span appears to be about 115 ft. The other end of these beams is fixed into the large beams forming outer walls of the building, and containing windows in their lower portion. It was found possible to place windows here (see page 405) owing to the fact that the concrete is entirely in extension underneath the slab. This supporting beam is, in reality, 12ft. high, and is composed of a double framework which is partly a beam with stirrups in the lower portion, and a frame of equal resistance in the upper portion above the floor, as will be seen by the plans.

The inside beams are 6 in. high, and they can take an equal resistance framework. The suspended beams are 39 ft. in span and also contain a framework of equal resistance.

The Other Floors.—The second floor and the roof are supported in the same manner as the first floor.

The ground floor is carried on pillars supporting the square areas, measuring 19 ft. 6 in. both ways.

The Loading Tests.—It will be noticed by the plan showing the test that the entire suspended area has been loaded with sand for a test load of 1½ cwt. per sq. ft.

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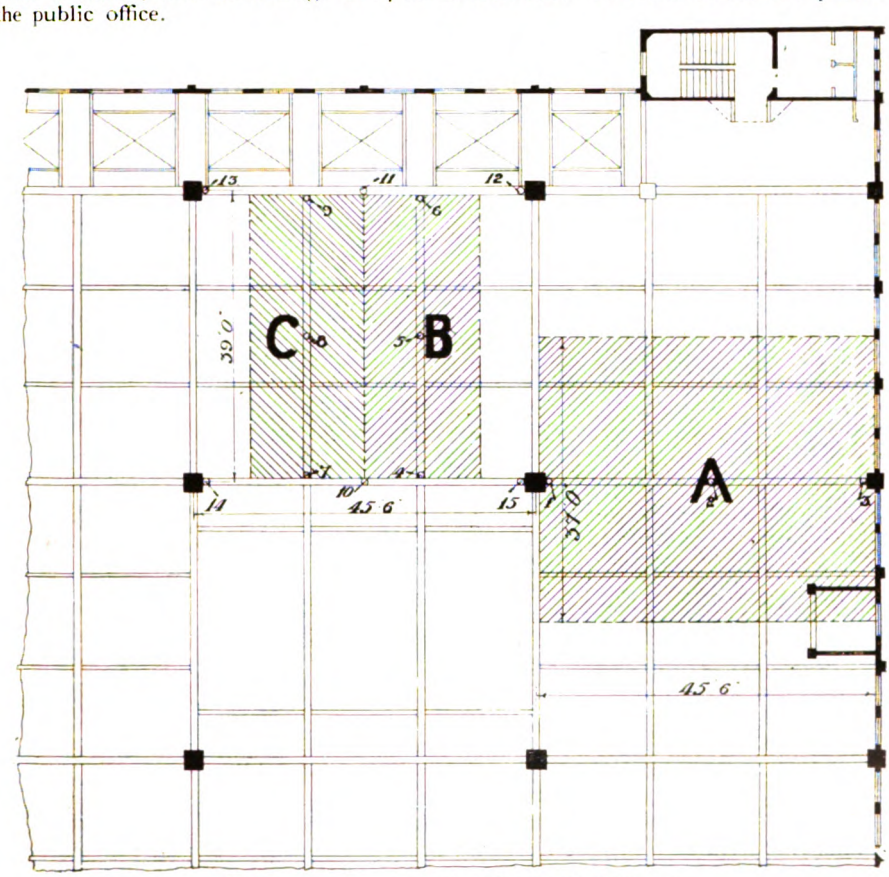
The maximum deflection of these beams was only $\frac{5}{16}$ of an inch, or in other words $\frac{1}{1497}$th of the span, whereas the maximum deflection allowed in the specification was $\frac{1}{600}$th of the span. The points of suspension to the upper beams gave practically no deflection.

The Loads on the Principal Pillars.—The loads on the principal pillars as transmitted to the footings are as follows:—Pillar No. 1, 448 tons; pillar No. 2, 225 tons; pillar No. 3, 370 tons; pillar No. 4, 334 tons; and pillar No. 9, 110 tons. The last pillar is round, with an average of 14 in. in diameter. It is one of the two pillars in the public office.



PLAN OF AREAS TO WHICH TEST LOADS WERE APPLIED.

The Loads on the Beams.—The beams supporting the first floor are the most important in the whole construction.

We give herewith some information concerning these beams. Beams b—Span 39 ft.; scantlings 10 in. × 30 in.; distributed load per foot run 3,035 lb.; maximum bending moment, 175,096 lb. Beams D—Span 45 ft.; scantlings 14 in. × 60 in.; uniform load per ft. run 8,239 lb.; maximum moment 1,511,581 ft. lb. Beams F—This beam is situated above the slab of the first floor and forms a parapet or wall. It has a span of 45 ft., and it receives the load of the beams B and I, which are suspended by means of flat stirrup irons. These are fixed to the framework of the beam F. The re-action of a beam b on its point of support at each end is equal to 57,412 lb. The re-action of the beams I on each point of support is equal to 20,128 lb. So that the beam F carries two concentrated loads of 77,540 lb. each. The maximum bending moment of this beam is 852,940 ft. lbs. The tests carried out on the first floor with a load of $1\frac{1}{2}$ cwt. per sq. ft. has produced a maximum deflection in the suspended beams of $\frac{5}{8}$ in. The other beams show practically no deflection.

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The Walls.—The walls throughout the building are in reinforced concrete, as described, and 6 in. in thickness.

Other Features.—The staircases are also in reinforced concrete, and the armature is smaller than that of a slab, as shown in the plans.

There is also a water tower containing about 7,000 gallons, and this is situated on the roof. The armature of this is also shown in the plans.

The watching galleries, ventilating shafts, and chimney shafts are made in reinforced concrete in a similar manner to the walls.

The front portion of the building contains the loading platform for the vans.

The public office, which contains two round pillars, supporting the inner wall of the building. Although these two columns are supporting a rather considerable load, it will be noticed that it has been possible to make them only of an average diameter of 14 in.

RECORD OF THE LOADING TESTS.

(See plan, page 411).

The following are records taken at the loading tests :—

Tests of Entire Areas marked B and C taken together.

March 24th.—The entire area was loaded with sand weighing about 1 cwt. per sq. ft. Deflections recorded :—

No. 4 ...	Nil	No. 10 ...	Nil
,, 5 ...	$\frac{1}{4}$ in.	,, 11 ...	$\frac{1}{16}$ in.
,, 6 ...	$\frac{3}{16}$ in.	,, 12 ...	Nil
,, 7 ...	Nil	,, 13 ...	Nil
,, 8 ...	$\frac{1}{16}$ in.	,, 14 ...	Nil
,, 9 ...	$\frac{1}{16}$ in.	,, 15 ...	Nil

March 25th.—Load of sand over entire area, $1\frac{1}{2}$ cwt. per sq. ft.

No. 4 ...	$\frac{1}{60}$ in.	No. 10 ...	$\frac{1}{60}$ in.
,, 5 ...	$\frac{3}{8}$ in.	,, 11 ...	$\frac{3}{16}$ in.
,, 6 ...	$\frac{3}{16}$ in.	,, 12 ...	Nil
,, 7 ...	$\frac{1}{60}$ in.	,, 13 ...	Nil
,, 8 ...	$\frac{5}{16}$ in.	,, 14 ...	Nil
,, 9 ...	$\frac{3}{16}$ in.	,, 15 ...	Nil

March 26th.—Load partially removed, reduced to 1 cwt. per sq. ft. Deflections recorded : Practically same as above ; the instruments show a tendency to move back.

March 31st.—Load entirely removed. Deflections recorded :—

No 4 ...	Nil	No. 10 ...	Nil
,, 5 ...	$\frac{1}{8}$ in.	,, 11 ...	$\frac{1}{8}$ in.
,, 6 ...	$\frac{1}{8}$ in.	,, 12 ...	Nil
,, 7 ...	Nil	,, 13 ...	Nil
,, 8 ...	$\frac{1}{8}$ in.	,, 14 ...	Nil
,, 9 ...	$\frac{1}{8}$ in.	,, 15 ...	Nil

Later readings showed that all the deflections were still further reduced.

Test of Area marked B.

TEST LOAD $1\frac{1}{2}$ CWT. PER SQ. FT.

March 10th.—A load of $\frac{1}{2}$ cwt. of sand spread over area marked B. Deflections recorded :—

No. 4 ...	Nil
,, 5 ...	$\frac{1}{16}$ in.
,, 6 ...	Nil

March 17th.—Extra load of $\frac{1}{2}$ cwt. of sand was added. Deflections recorded :—

No. 4 ...	Nil
,, 5 ...	$\frac{1}{12}$ in.
,, 6 ...	$\frac{1}{30}$ in.

March 18th.—Deflections recorded :—

No. 4 ...	Nil
,, 5 ...	$\frac{1}{8}$ in.
,, 6 ...	$\frac{1}{20}$ in.

March 19th.—With total load $1\frac{1}{2}$ cwt. per sq. ft. Deflections recorded :—

No. 4 ...	Nil
,, 5 ...	$\frac{5}{16}$ in.
,, 6 ...	$\frac{1}{10}$ in.

Test of Area marked A.

TEST LOAD $1\frac{1}{2}$ CWT. PER SQ. FT.

March 9th.—One cwt. of sand spread over entire area.

March 10th.—Deflections recorded :—

No. 1 ...	Nil
,, 2 ...	$\frac{1}{60}$ in.
,, 3 ...	Nil

March 12th.—Extra load of $\frac{1}{2}$ cwt. of sand added.

March 13th.—Deflections recorded :—

No. 1 ...	Nil
,, 2 ...	$\frac{1}{12}$ in.
,, 3 ...	Nil

March 15th.—Deflections recorded :—

No. 1 ...	Nil
,, 2 ...	$\frac{1}{10}$ in
,, 3 ...	Nil

The final reading after removing load was, in centre of beam (Instrument No. 2), $\frac{1}{14}$ in.

NOTE.—The ratios between the maximum deflections and the spans were as follows :—

Test A.—Maximum deflections, $\frac{1}{520}$ of span.

Test B.—Maximum deflections, $\frac{1}{1457}$ of span.

Tests B and C together.—Maximum deflections, $\frac{1}{1497}$ of span.

The maximum deflection allowed was $\frac{1}{850}$ of the span.

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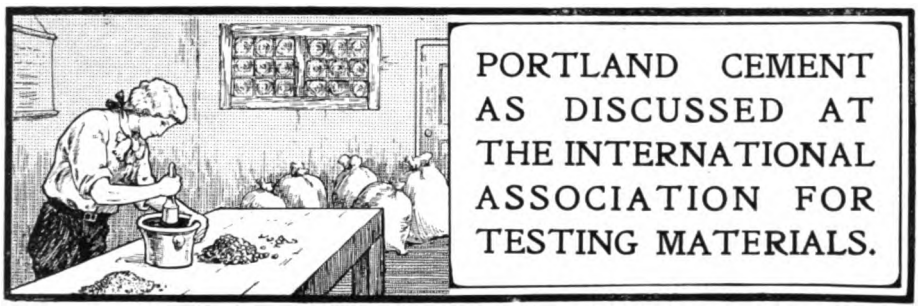

As indicated in the editorial columns of our October issue, various papers and reports on Portland Cement were presented at the recent Copenhagen meeting of the International Association for Testing Materials.

The more important of these papers will be published in this journal, not only as valuable contributions to a much discussed subject, but also as of special utility for reference purposes.—ED.

INTERNATIONAL CONGRESS FOR TESTING MATERIALS.

The following paper was presented on the occasion of the International Congress on Testing Materials at the meeting of Section B, which dealt with concrete, reinforced concrete and Portland cement. Papers dealing with Portland cement were taken on Wednesday, Thursday and Friday, September 8th, 9th and 10th, Captain Grut, of the Danish Royal Engineers, acting as local Chairman and the Hon. Foreign Presidents of the section also being present.

PROGRESS IN THE METHODS OF TESTING HYDRAULIC CEMENTS.

Report presented by R. FERET, Boulogne-sur-Mer.

(*Translated by A. R. Liddell, Charlottenburg.*)

Generally.—At the Fourth Congress of the International Association held in Brussels in 1906 Committee No. 22 presented and obtained the adoption of the results of extensive labours in which they had been engaged since the foundation of the Association, with a view to the adoption of uniform methods for the testing of the different materials the study of which enters into the domain of this latter body.

But in view of the difficulties of all kinds inherent in a tentative international unification of the kind the Committee has been able to give official recommendation to hardly any other methods than to such as have been in use for a long time and already have the support of established custom, and such a solution can only be of the provisional character inseparable from every idea of progress.

In this report it is proposed, in so far as the testing of hydraulic cements is concerned, to pass in review the methods that are capable at a later time of being advantageously added to or substituted for those of the Committee, whether because they have not been thought of till after the conclusion of the latter's labours, or because, although already more or less known, they were not considered to have stood the test of experience to such a degree that they could at this stage be sanctioned by the Association.

In view of the very narrow bounds which have been set for this work, the reporter will confine himself to an examination of the principles underlying the methods, without going into the details of the conduct of the tests.

Chemical Composition.—Hitherto the International Association have not concerned themselves with the methods applied to the analysis of the hydraulic cements, and, moreover, it is thought that opinions may differ as to the opportuneness of the eventual inclusion of these in this kind of investigation, which seems to belong rather to the domain of pure chemistry than to that of technology. The conditions for the reception of the products in question, however, always contain clauses relative to the

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chemical composition of these, and it often happens that difficulties arise from the want of uniformity in the percentage of this or that simple element found in several different laboratories. Also the Association should ask themselves whether, in the case of limes, cements, and such-like products, the work of progress would not be furthered by the indication of a practical and uniform standard method of chemical analysis, which would be appealed to in contested cases, without such method at the same time arrogating to itself the right to take the place of all others that the individual experimenter might judge to be better calculated to attain some special end he might have in view, whether the question at issue should be the determination of elements only occasionally met with in the cement, or analyses of great precision, or should on the contrary bear reference to rapid and more or less approximate chemical tests.

A start in this direction has already been made in the United States of America, where an important piece of work has been accomplished in the fixing of a uniform method for the analysis of the crude constituents, as of the manufactured products of the hydraulic cement industry.

At the same time it would no doubt be convenient that the Association should take the question into consideration as to whether they should also indicate methods for certain chemical tests of a more conventional character, such, for instance, as the weight constituent of soluble silica, the proportion of which evidently depends on the conditions under which its dissolution is attempted.

Tests of this kind attach to investigations into chemical constitution, that is to say to the part played by the various elements and to their grouping, an important question but one which may still be made the subject of lengthy discussion; on the other hand, the chemical composition of a material, as expressed by the different percentages of the primordial elements which it contains, can indeed be exactly determined in each case, but affords very little clue to the quality of the product.

Specific Gravity.—Specific gravity is a precisely defined quality, and there is no lack of methods for its exact determination, so that further progress of any importance in this direction is hardly conceivable.

The question is far from being exhausted, however, and the value to be attached to such determinations in view of the differentiation of the hydraulic cements among themselves, or of the appreciation of their qualities, is still under discussion. Opinions differ also as to whether it is better to work with the cement in its market condition or after recalcination.

Apparent Density.—Unlike specific gravity, apparent density is an entirely conventional conception, and varies with the method of measuring it.

The method adopted by the International Association at the instance of Committee No. 22 is one that gives the weight of unshaked litre under very comparable conditions, and does not seem to stand in need of improvement.

As in the foregoing case, however, there is room for discussion as to the utility of this test, as well as of that of the simultaneous determination of the weight of a shaked litre under certain clearly defined conditions.

Fineness of Grinding.—The use of sieves for the separation of hydraulic cements into grains of different sizes and for the determination of the proportions of each of these has been the subject of numerous criticisms. The two principal of these bear reference, on the one hand, to the extreme difficulty of making the metallic meshes perfectly regular and of a rigorously defined uniform type as regards thickness and spacing of the wires, and on the other to the impossibility of separating the finest particles contained in the powdery substance by means of sieves with very closely spaced wires.

Various experimenters have endeavoured to effect a methodical separation of the powders by levigation experiments, made, either by shaking them in a liquid, which is then poured off with the fine particles remaining in suspension after a fixed period of repose, or by working them in a liquid or gaseous current of regulable speed, which carries away the finer and lighter particles. By a variation of the period of repose in the first case and of the speed in the second the powder may be separated into grains of different sizes to any desired degree.

A method of sufficient simplicity, however, which above all can be defined in a sufficiently precise manner in all its details, so that the Association could at once

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recommend it from the point of view of international unification of tests of this kind, does not appear to have as yet been discovered. At the most, expression may be given to the opinion that the use of a current of air would probably be more practicable than that of a liquid.

The question has, moreover, been already submitted to the study of a special commission.

Homogeneity. — The experiments to ascertain whether a cement is homogeneous and, in case of need, to determine the foreign matter contained in it, which were not foreseen by Committee No. 22, should admit of being made by different methods according to the nature of the impurities suspected, and their strict unification does not therefore appear to be possible.

The methods most often resorted to consist in the separation of the powder, either into grains of specific weights rising by regular gradations according as they float or sink in liquids of suitable densities, or into grains of different sizes, by sifting or by levigation, followed by the examination with the microscope or by the separate analysis of the different kinds of grain obtained.

Constancy of Volume.—Numerous methods have been applied consisting in the moulding of the paste in the forms of cakes with thinned edges, of little balls, or of cylinders, and in the exposure of these test-samples to the action of air, water, or steam, either hot or cold.

It is clear that these different tests are not all equally severe; often indeed their results may be such as to vary the order of the cements as classed by them.

The only ones which are in somewhat more general use are the test on cakes immersed in cold water, which, however, allow products of doubtful quality to pass unchallenged, and the boiling water test on cylinders confined in a thin divided metallic covering provided with two long amplifying pointers the increase of the interval between which is measured (Le Chatelier method). In view of simplicity and rapidity, and the concrete numerical form in which its results are given, this method constitutes a real progressive step, and it has been quickly adopted without opposition in most of the specifications of conditions of delivery.

As to the methods which consist in the very exact measurement of the length variations of small prismatic bars, their very delicacy limits their application to certain investigations of a scientific nature, and, moreover, they do not appear to be altogether above criticism.

A special commission is still studying the question of tests on constancy of volume.

Action of Sea Water.—A method at once sure and rapid of determining the capability possessed by hydraulic cements of resisting the decomposing action of sea water and sulphurous waters has not yet come into general use, and the method commonly employed consists simply in immersing the mortar into sea water and observing it for as long periods as possible. The results given by this test vary, however, according to the composition of the mortar and to the conditions of its immersion, and the experimenter often has to wait for long periods before he observes any signs of disintegration, and even then such signs may be of a doubtful nature. It is in fact necessary to avoid certain accessory phenomena, such as the formation of superficial crusts, which, according to circumstances, may retard or accelerate the decomposition or hide its effects.

More scientific and expeditious methods have been proposed, and it will be a point of importance that experiments be made on these in as many laboratories as possible.

Duration of Setting. — The use of the Vicat needle continues to be the only practical method in use for the determination of the duration of the period of setting of hydraulic cements. The appliance is one of extreme simplicity, but its readings are sometimes uncertain, especially when it is a question of determining the end of the period; besides, the readings are of a purely conventional character and do not appear always to bear a sufficiently constant relation to the duration of the setting period of the mortars of actual practice.

The discovery of more exact methods has therefore been attempted.

Methods of testing based on the measured variations in the electric resistance of mortars while hardening have not given results of interest.

Other investigations have aimed at the definition of the setting by the determination of the temperature of the mortar during its continuance. Reasonably regular

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curves were obtained by this method, which however were dependent on the testing conditions and corresponded with chemical phenomena the relation of which to the change of consistency called setting has not yet been quite clearly established.

The principal nature of the method to be employed may be the ascertainment of the time, reckoned from the commencement of the gauging, during which a given mortar can with impunity be further used without having to be revived by a fresh addition of water or a too violent mechanical treatment.

Mortars for Testing.—According to the country in which the strength-tests are made, the materials used for them consist either entirely of sandy mortars or both of mortars and of pastes gauged without sand; these pastes are more easy to define than the sandy mortars, and can be manufactured under conditions which more readily admit of comparison; but the value of the information furnished by them is a matter open to argument.

The mortars are composed of one part of cement and three parts of a so-called standard sand, the size of grain and nature of which exert an influence on the results of the tests.

Several countries have made exact definition of their standard sand and taken proper measures to ensure and control the purity and invariability of the material provided; but it has not yet proved possible to extend this system so far that choice can be made of an international standard sand, and one of the Committees of the Association is charged with the task of preparing the way for a unification of this kind.

It has long been the custom to moisten the standard mixtures with relatively small quantities of water, so that they have the consistency of moist freshly-turned earth, and to belabour them energetically in the moulds, either by hand, with the spattle, or by machinery, according to rules so formulated as to ensure that the mortar undergoes a certain fixed amount of mechanical work. But the objection has been made to this method, that an appraisement based on the comparison of such mixtures might result in the classing of the different cements in an order that did not correspond with the relative strengths of the much softer mortars of actual practice, and in several countries some of the great administrations and technical associations have now adopted mortars of plastic consistency cast in the mould without ramming for their standard strength-tests. For the generalisation of this method, the principal difficulty remaining for solution is the exact definement of the standard plastic consistency and of the method of filling the moulds. The same Committee of the International Association is entrusted with the study of this question.

In regard to the method of keeping the samples from the time of gauging till that of the breaking-test, it has remained practically the same in spite of the investigations still actually in progress in some countries aiming at the discovery of another one, which shall allow of a better differentiation between the Portland cements properly so-called and various other competing products.

Strength Tests.—The two methods of testing in almost universal practice are that by tension, made on briquettes formed to a model which resembles the figure 8 and is almost the same in every country, and that by compression applied to cubes or to fragments of the briquettes. According to the country in question, preference is given to the former of these, which is the more easy of application, or to the latter, which appears to give a better differentiation of the different products.

The proposal has been made to replace the tensile tests by flexure-tests applied, either by a central load or by a uniform bending moment, to prisms of square section which are easy to define and to manufacture, and the halves of which are then available for compression tests. This method has obtained a favourable reception from the Association, and has been relegated to the Committee above mentioned.

Another method of testing, which ought still to be found, is that by shearing, the results of which would afford a basis for the calculation of the fraction of the cutting force which concrete could without danger be designed to support in the reinforced concrete structures; but there is no method yet known which, while free from every source of systematic error, will give the exact measure of this resistance.

Accelerated Tests.—It was formerly hoped that the work of time might be supplemented in the strength-tests by that of agents, such as heat, which might be capable of hastening the reactions to which the hardening of the hydraulic cements is due.

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Numerous experiments have shown that, whatever the method employed, the strengths obtained never show any definite relation to those of the same cements when kept under the normal conditions for more and more lengthy periods, and it would appear that the idea of seeking a solution of this problem had now been almost given up.

Adherence.—Placed on the programme of the International Association for solution, the question of adherence-tests formed the subject, at the Brussels Congress of 1906, of a general report in which it was particularly set forth, on the one hand, that the testing methods should render possible the measurement of the adherence, of each possible mortar to each possible material, and on the other that they must admit of distinction being made between normal adherence and tangential adherence, maximum forces tending to hinder the detachment according as the effort is exercised normally to the plane of contact of the two materials or in the plane itself. In regard to the methods proposed for the measurement of the two kinds of adherence, it would have been imprudent to adopt them without verification, and the reporter himself asked that experiments should be made in different laboratories before the Association declared their approval of them.

An adherence of another kind, the interest in which increases from day to day, is that which tends to counteract the sliding of bars of metal in reinforced concrete. This is a resultant of the tangential adherence which has just been defined, of the resistance opposed by the concrete to being itself sheared by superficial roughness of the reinforcing metal, and finally of the pressures exercised between the iron and the concrete as much by the alterations of volume accompanying the hardening of the latter as by the transmission of the force efforts set up in the block by the action of external loads. This resultant, which may be called the resistance to gliding, is, however, of a very complex nature; our knowledge of the law by which it varies from one point to another of the surface of contact of the two materials is very imperfect, and it is in fact impossible to calculate its value with absolute exactness, in spite of the numerous experiments by the aid of which its measurement has been attempted.

CONCLUSIONS.

Summary.—To summarise the foregoing, the following conclusions may be arrived at:—

(1) Apart from the old methods retained without any modifications of importance by Committee No. 22, the Association have not yet adopted any of the testing-methods of which the special Committees have made study, and these Committees have moreover considered themselves unable to formulate definite proposals in favour of this or that new method.

(2) At first view a stagnation of this kind may appear regrettable. But extreme prudence is imposed on the Association in the choice of testing-methods to which they are asked to give the support of their authority, and it is of importance that they should not officially patronise any such which has not previously been duly checked by a number of competent experimenters.

(3) The part to be played by the Committees of the Association is precisely that of promoting the elaboration of better methods than the ones previously in use, to verify these by parallel experiences obtained in different laboratories, and, if need be, to further improve them. When sufficiently developed, these methods will impose themselves on technicists without further ado, and it will only remain for the Association to affix to them the stamp of their official sanction.

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It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.

The method we are adopting, of dividing the subjects into sections, is, we believe, a new departure.

We trust that this chapter of our Journal may become a recognised reference medium as to the latest views of those who can speak with authority.—ED.

INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.

ARTIFICIAL STONE FOR FOOTWAYS.

PAPER by Mr. R. BROWN, A.M.Inst.C.E.

Mr. Reginald Brown, A.M.Inst.C.E., Engineer and Surveyor to the Southall-Norwood District Council, read a paper on "Artificial Stone for Footways" to the members of the Institution of Municipal and County Engineers at their annual meeting, held recently at the St. Pancras Town Hall. Mr. W. Nisbit Blair, M.Inst.C.E., Borough Engineer of St. Pancras, presided.

THE use of artificial stone has become so general that every municipal engineer should be *au fait* with the methods of manufacture and the comparative qualities of the various makes, so that he may be able to advise his authority on the acceptance of tenders. It was not suggested that any municipal engineer was incapable of advising on the subject, but, as they all knew, with a good many local authorities the question of £ s. d. was the chief factor which guided them in selection, and it was sometimes difficult for an engineer to persuade his authority—consisting probably of a majority of non-technical men—to purchase a higher-priced stone which the engineer knew to be the cheapest in the end. As it would, in a paper of that sort, be invidious to refer to any particular manufacture by name, the author would content himself with "reference by number" when mentioning tests, but he would give members in confidence the various "number" references.

Materials Used.—The materials in general use for the manufacture of artificial paving slabs were granite chippings and cement, but in some cases crushed York stone or crushed clinker took the place of granite chippings.

Cement.—The best firms were very particular as to the quality of the cement used by them. They had their own specification for the cement, which followed closely on the lines of the British Standard Specification. The good quality of British cement was so well secured and assured from the best works that the different results obtainable under breaking and wearing tests must be attributed to other causes than the cement.

Aggregate.—The kind of granite used depended in a great measure upon the position of the works, their nearness to the quarry and the cost of carriage, but it was a *sine qua non* that the hardest granite should be used. The specific gravity of the granite used would have some bearing upon the number of slabs to the ton, and consequently upon the cost at which the slabs could be supplied, and also upon the durability of the slabs under wear. The granite chippings used generally come from Leicestershire quarries; they were tough and hard, and made excellent material, but even with these granites the specific gravity varied from 2·63 to 2·99, so that the slabs made would also vary in weight. Crushed clinker produced a stone which was not so heavy as those made with a heavier and more dense aggregate, such as granite chippings.

Sizes of Aggregate.—The tendency was to use granite chippings crushed to ¼-in. gauge, but as the chief aim is to obtain as dense a concrete as possible, it would be interesting to know whether this could not be attained and a stronger slab manufactured by the admixture of granite chippings so graded in size and in such proportions as would render the percentage of voids a minimum, and by this means use a smaller quantity of cement.

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Cleanness of Aggregate.—Tests had been made from time to time as to the value of eliminating the fine dust from granite chippings preparatory to making up the test cubes, and whilst it was evident that dust, as dust, should not be present, it appeared that if the material were properly selected a small amount of granite dust, as *very* fine chippings, affected the strength to a very small degree so long as the dust *plus* the cementing material did not exceed the amount required to fill the voids in the crushed granite, and so long as the cementing material could surround all the particles.

Voids.—A fairly accurate method of finding the percentage of voids in the granite chippings was to take a quantity of the aggregate, place it in a vessel of known capacity, shake down and level and add water from a vessel of known capacity. The amount of water used after taking into account that taken up by the aggregate would give the volume of the voids, and from this the percentage could be ascertained. The author had carried out several tests to ascertain the percentage of voids in granite chippings, such as was used for the manufacture of artificial stone paving, and found that a fair figure to take was 45 to 50 per cent. by volume. As the chippings were measured loose the percentage of voids would be less in tamped or machine-made concrete.

Types of Stone.—The manufacture may be conveniently divided into three heads: (1) Machine made; (2) hand made; (3) partly machine and partly hand made.

Apparatus Used.—The apparatus used in the manufacture of machine-made slabs consisted of automatic appliances for the accurate measuring of the various constituents, mixing machinery, moulds, and presses. There was no doubt that an accurate measuring of the constituents was essential if the best results were to be obtained, and from the tests carried out by the author that became very apparent by reason of the varying specific gravity of the concrete cubes obtained from the same makers. This might, of course, be due partly to the method of mixing adopted, but even with careful mixing the specific gravity of cubes from the same slabs did not agree. As far as possible it was advisable to remove the human equation from that part of the manufacture of paving stones, and therefore it was apparent that machine mixing was to be preferred, although mixing by hand would have its adherents. Some companies making stone by hand used wood moulds, whilst others used those made of steel. The former were cheaper in first cost but more costly and troublesome to maintain, as they became ragged at the edges and consequently affected the arrises of the manufactured stone. Steel moulds, on the other hand, gave sharp arrises to the stones, and were practically permanent and indestructible. In machine-made slabs the wet concrete was filled into the moulds or mould forming part of the machine, a loose, but closely fitting and perfectly true metal plate was first placed in the mould, the mould was then filled with concrete, which was levelled and was consolidated by means of a ram which commenced with a pressure of 500 lb. per sq. in., and was increased by intensifying to about 3,500 lb. per sq. in.; when this operation was completed the slab and loose plate was forced out of the mould and taken to the silicating tanks, or indurating tanks, or placed in drying-sheds to mature, some firms adopting the method of keeping the slabs damp in the sheds by watering them occasionally. It was claimed that a machine-made slab was more dense and durable than a hand-made slab. When the slab was made by hand the wet concrete was placed in the mould and was "tamped" thoroughly to remove all air holes as far as possible, some firms using shaking machines to attain the same object.

Machine-made v. Hand-made Slabs.—So far as density was concerned, it appeared on the face that machine-made slabs should be heavier than hand-made slabs; but this did not occur in practice to a very noticeable extent. The author had had slabs made from the same aggregate in the same proportions both by machinery and by hand, and he found that, in some cases, the hand-made slab had been the heavier of the two. So far as the wearing qualities were concerned, the tests given later on in this paper speak for themselves.

Absorption of Water.—To test the absorption of hand-made against machine-made slabs the author had some bars of concrete made 24 in. long by 2 in. wide and 2 in. deep, and after three months he found that the hand-made slabs contained about 6 per cent. of moisture against 4½ per cent. in the machine-made slabs. After they had been dried and weighed the bars were steeped in water for a period of 18 hours and then weighed again, and it was found that the hand-made slabs had absorbed slightly less moisture than they originally contained, whereas the machine-made slabs had absorbed slightly more, but the difference was so slight in the former as to be hardly noticeable, whereas in the latter the percentage was much greater.

Breaking Strength.—So far as that was concerned, the hand-made slabs were in many instances found to be quite as strong as machine-made slabs. Thus it would appear that properly made hand-made slabs were as good as machine-made slabs.

Density of Slabs.—The average weight of a cubic foot of concrete composed of 3 of granite chippings to 1 of cement might be taken to be 150 lb., and a stone at this weight would represent a specific gravity of 2·4; of this the moisture must be taken to be 5 per cent., bringing down the specific gravity of the cement and concrete to 2·28. In the above proportions the granite chippings would represent a specific gravity of 1·72, leaving the voids as 35 per cent. to 42 per cent., according to the weight of the granite used for the chippings.

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Durability.—There was no doubt that the best test for durability was the actual wear in the stone when laid in a thoroughfare subjected to atmospheric influences. A considerable number of years had elapsed since some of the artificial stones first came into use, and members of the Association had had ample opportunities of gauging the wear of such stones under ordinary conditions. It was, however, difficult to compare one stone with another when laid as footway paving, as they could not be subjected to exactly similar conditions. The author had, therefore, tested some scores of samples of stones for their wearing qualities. The stones tested were as follows: Victoria, Aberdeen, Adamant, Empire, Non-slip, Granolite, Imperial, Thames, Excelsior, Croft, Cliffe Hill, Alexandra, Atlas, and a paving made from destructor clinker. The manufacturers were good enough to have the cubes cut out from the actual slabs, these cubes being as near as possible 2 in. by 2 in. by 2 in. For wearing properties the author adopted the "rubbing test" as follows: A small vertical gas-engine of 2½ h.p. was requisitioned for the purpose, and an emery wheel attached to an extension of the fly-wheel axle. The cubes were held in a wooden frame on to the face of the emery wheel by means of an iron bar pivoted to a rigid wooden frame, extending over the stone under test with a weight depending from the further end.

By this means an equal pressure was applied throughout the tests to all the stones and the human equation eliminated. Each test consisted in allowing the engine to run for 15 minutes at 220 revolutions per minute. The results of these tests proved that the majority of the stones on the market showed comparatively little wear, the hand-made comparing very well with the machine-made slabs.

Maturity.—It goes without saying that a slab, to be suitable for footway paving, should be "mature" and the general rule was to insist upon a guarantee that the slabs shall be twelve months old before delivery on the works. It was difficult, of course, after the slabs had been delivered on the works to subject all to tests to prove their maturity. Of late years, no doubt owing to the large number of manufacturers, a specified breaking stress had been applied and required by municipal engineers, and manufacturers were now alive to the fact, and in many instances the test was applied by the manufacturers at their own works, and a certificate issued with all consignments; but the majority of municipal engineers liked to see the test applied themselves. The best manufacturers were only too willing to submit their stones to any reasonable breaking test in the presence of the engineer, as it was to their interest entirely to supply a stone which would meet with approval. The result was that several tests had been suggested and adopted by different municipal engineers, but the author thought it would be agreed that a general test should be adopted, so that manufacturers might know what to expect, and so that all manufacturers might be placed on the same and equal footing. The usual thing was to select a certain number of stones out of a specified consignment, and if any or a certain proportion of those stones broke under the test to be applied, the consignment was rejected. Owing to the uncertain mixing and manufacture of slabs it was therefore advisable to adopt a reasonable breaking test, and not one which might possibly be reached in exceptional cases. In order to ascertain the strength of a beam as compared with any load it may have to carry, it was necessary to ascertain the nature and extent of the external forces at work tending to break a beam across, together with the internal forces which were resisting this tendency to rupture. It was a well-known fact that in timber beams the upper half was in compression and the lower half in tension, and although the constituents of concrete were granular and not fibrous, it would be assumed that similar strains were set up. When a beam was loaded uniformly the bending moment, graphically, took the form of a parabola, the greatest moment being at the centre, and was represented by $\frac{Wl}{8}$, where W was the total load and l the span. When the load was concentrated at the centre the bending moment, graphically, took the form of a triangle, and the formula became $\frac{Wl}{4}$; hence a beam loaded uniformly would bear twice the load as when the load was central. There were many degrees between each of those extremes, and the results obtained by various manufacturers and municipal engineers might be, and no doubt was, due to the fact that the loads were not applied centrally; that could be obviated if the tests were reduced to an equivalent central load, or, better still, if the central load was generally adopted. The most severe breaking load that could be applied was, therefore, to concentrate the load at the centre of the slab. The load should be applied on as small an area as possible, otherwise it would take somewhat the form of a partially distributed load. If the load could be applied on a knife edge across the centre of the stone it would be all that could be desired, but as the general rule was to use slabs as the load, it became necessary to apply it on a flat surface. Manufacturers could no doubt use some form of hydraulic apparatus in which the load could be applied on a knife edge and applied gradually, or the load could be applied by means of weight sliding on a long lever arm; by either of these means the actual breaking load or the test load could be applied without jerks and applied at the proper place. They had, however, to deal with the tests as they existed. Experience had shown that 4 in. was about the narrowest width that could be used under those conditions. It was therefore suggested that when slabs were used as the load the slab under test should rest on knife edges, across the width of the slab, placed 11 in. on either side of the centre of the slab, and the load applied, stone by stone, as carefully as possible, to prevent jarring. A good method was to use slabs 2 ft. 6 in. long as the

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load, placed with their long axes alternately across the width and length of the slab under test, thus giving a "hand hold" during loading. The resistance afforded by the internal structure of the slab was given by a number of closely adhering grains. It was difficult to state the actual position of the neutral axis in any particular slab, but if it was taken along the centre of the depth, the cemented grains below the centre line were subject to tension, and the grains above the centre line were subject to compression. On that assumption the grains on the lower face would be subject to the greatest tensile stress, but the area subjected to tension would depend upon the position of the neutral axis. Simple concrete would fail in tension long before its failure took place by compression, hence that stress was generally taken. From extended experiments upon both slabs and test bars the author found that the modulus of rupture, or the "tensile strength per unit of area of extreme fibre" of concrete as used in paving slabs, might be taken as from 770 lb. per sq. in. to 1,155 lb. per sq. in., and at those figures the concentrated breaking loads should be from 20 cwt. to 30 cwt.

Specification.—After tests spreading over several years, the author had adopted the following specification for artificial stone paving: The paving to be obtained from an approved manufacturer in stones not less than 4 ft. in superficial area, unless otherwise sanctioned, and to be 2 in. thick. The manufacturer or manufacturers must give a written guarantee to the contractor and the surveyor that the stones proposed to be supplied by him or them have been in stock at least 12 months before delivery upon the works. The stone to be made of granite chippings and Portland cement, well mixed together. Either machine-made or hand-made slabs would be accepted. The stones would be required to have both top and bottom faces equal in character and finish, the stones to be out of winding, the edges and arrises to be true and clean. When the stones were delivered on the job the surveyor would select a number of stones in the proportion of four slabs for every street, or for every 400 yds. supplied, whichever was the smaller, and a test would be applied in the following manner: "The stone to be tested will rest on knife edges (placed 11 in. on either side of the centre of the longest dimension of the stone), and a piece of 4 in. by 3 in. timber laid flat across the centre of the stone at its narrowest dimension, and the load applied by means of similar slabs piled one on the other. If the stones do not comply with the requirements above specified, or (on testing) any or either of the stones break at less than 20 cwt. the whole consignment will be rejected, and must be removed from the works on notice from the surveyor. The contractor must provide in his price for the necessary assistance for testing, and also for any stones broken during the tests. The stones on the approved list are (here follows list of five), but the surveyor may approve of the use of stone of other makers so long as they comply with the above requirements."

DISCUSSION.

Tests.—*Mr. Walker Smith* (Edinburgh) was of opinion that this question did not receive the consideration that was due to it. Some time ago he sent out 150 inquiries, and of respondents there were only about three who employed any test at all. Mr. Brown came to their rescue and pointed out that it was necessary to test for porosity and abrasion, and after he got them to those giddy heights, he suddenly dropped them to earth again by going on to say that his own test was for tension. Did he include tests for density, and porosity, and abrasion as well as tension? It was scarcely fair to ask Mr. Brown to standardise this commonplace material for them, but if he could reasonably and conveniently carry his experiments further they would be all deeply indebted to him. But he thought it would be a much more valuable specification if it came from the Council of the Institution, and if they could appoint a committee and adopt a standard specification for this material, which they were all using, they would confer a benefit upon the members.

Specification.—*Mr. E. Y. Harrison* (Wellingborough), agreed with Mr. Walker Smith as to the specification. He thought it might be made more complete. Nothing was said as to the proportion the cement should have to the aggregate. He should like to suggest to Mr. Brown whether it would not be necessary to consider whether the slabs would be satisfactory no matter what amount of cement might be in them. It was rather difficult to judge by analysis the amount of cement that was in a slab. He knew most firms allowed for 3 to 1, but it was quite possible that the slabs might be made in 5 to 1 proportion, and still stand the test. The specific gravity had a good deal to do with the price when they considered that the slabs were bought by the yard and not by the ton. He would like to know whether the result of Mr. Brown's test was through a number of tests made with the same material, whether the tests were purely dry tests, or whether he made any wet tests?

Voids.—*Mr. E. Willis* (Chiswick), remarked that the proportion of voids in granite chippings was quoted as 45 to 50, and in the made-up slabs 35 to 42. That seemed a very large proportion of voids to a finished slab. He suggested that other districts should follow the example of Chiswick—though he did not—of laying samples of slabs by different makers, so that the Council and the engineer were able to watch the wear of the slabs. Of course, it could not be useful for some years to come, but it was useful for the future. The amount of absorption as between hand-made and machine-made slabs was peculiar. With reference to the units of breaking load of from 20 or 30 cwt., he would like Mr. Brown to give the size of the slab, or whether he referred to any unit of area. He thought it was very good of Mr. Brown to give them detailed information of his experiments. He knew he had been

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experimenting for some time, as he had heard of it from manufacturers who were beginning to quote Mr. Brown.

Size of Slabs.—*Mr. F. R. Phipps* (Basingstoke), said that the only point he would like to ask Mr. Brown was as to the size of the slabs. He said the paving should not be less than 4 ft. superficial area; that he took to be not less than 4 ft. sq. He had a liking for small slabs, and had used 2 ft. by 2 ft. and 2 ft. by 18 in. By using the smaller slabs they obviated the fracture which often happened to the 3-ft. slab.

Appearance and Comfort.—*Mr. E. B. B. Newton* (London), remarked that there were matters of great importance with regard to paving which were not mentioned in the paper. Cheapness was not the only object to be aimed at by the local authority in providing footpaths; there were also appearance and comfort to pedestrians. He did not notice any mention of those, but he thought they should be taken into consideration in deciding upon the tests. He did not suppose he should be in order in discussing natural stone paving because the paper was restricted to artificial stone paving. He felt bound to say that, in London at any rate, there was one important feature in which the natural stone possesses advantages that no artificial stone could obtain, though there might be differences in this respect between the different classes of artificial stone. It was the taking up and relaying for openings by the statutory authorities. There were many artificial stones which, when they had been subject to heavy traffic, could not be relaid on the footpath. Though the slabs might have been down only a few years they had to be scrapped; whereas, with natural stone, which could be redressed, there was a great economy to the local authority.

Wear.—*Mr. O. E. Winter* (London) agreed with Mr. Newton as to appearance and comfort in paving. He found after some years flags composed of a granite aggregate were inclined to wear slippery, and therefore he used very extensively where gradients were steep flags composed of a York aggregate. He found these flags of excellent wear, and they gave a superior foothold to flags composed of granite. The repair of such a footpath laid with flags was much more easily carried out than with *in situ* paving.

Gradients.—*Mr. W. Fowlds* (Keighley) asked Mr. Brown what gradient he found was the limit for putting down artificial flags with a granite aggregate. They had found in Keighley, where they had put them in streets of more than 1 in 30 that they had had to pull them up again. Keighley was a town where they had a number of workpeople who wore clogs, and that might be the cause. Artificial flags were of very limited use. The constant pulling up and the wastage on concrete flags made the expense very great indeed, and it was only in limited places that they found the use of artificial flags advantageous.

Hand-made Flags.—*Mr. I. S. Pickering* (Cheltenham) dealt with the question of hand-made flags *versus* machine-made. He had a machine which was turning out about 12,000 yds. per annum. His opinion was that a better wearing slab could be made by hand. The disadvantage of the machine-made slab was that the aggregate had to be ground so finely in order to get the arris sharp that it took away a good deal from the durability; whereas, in the case of a hand-made flag it could be made with ¼-in. and ¾-in. chippings, and made a harder and more durable flag. Those who had not had much experience in clinker-made slabs, he would like to take the opportunity of warning them against the use of that material, unless great precautions were taken.

Flags.—*Mr. T. S. Picton* (Eccles) said they had laid in Eccles 4,000 yds. of concrete slabs, and in a Lancashire town where they had large numbers of mill hands wearing clogs, the slabs were very favourably spoken of. The tests given in the paper were good, but he thought the best test was that of putting flags down, keeping them under observation, and noticing their wear. They had concrete flags which had been down 15 years and were in wear at the present time. He had laid concrete flags on a gradient of 1 in 20; that was a Thelkeld flag, and he had received no complaints of accidents on that road.

Making Concrete Flags.—*Mr. MacBrair* (Lincoln) said he had been making concrete flags for 20 years. He commenced making them with granite chippings, but found them so slippery that he gave that up. He was now making them of granite dust and slag dust, and it answered very well. The price of their York flags was 4s. 6d. per yd., and they could make these flags for 2s. 6d. per yd., which was a very substantial saving. They made them by hand labour. The size of the flags was 3 ft. by 2 ft. and 2 ft. by 1 ft. 6 in. They had a very pleasant appearance, and could be made at practically half the cost of York flags; they looked better, lasted longer, and therefore they would keep to them.

The Reader of the Paper Replies.—*The Lecturer* thanked the mover and seconder of the vote of thanks, and the members for their reception of the paper. The whole discussion, to his mind, had been taken on the wrong lines. He wanted to draw from members the methods they would suggest in testing slabs. When they required slabs they got all kinds of firms sending in tenders; some were known and some were unknown. What methods were the engineers going to recommend their Councils to adopt to get the best slab for the price offered? This was a question for a committee of inquiry. What they wanted was a specification to which every manufacturer could adhere, and then every

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manufacturer would quote his price on the same basis. If a manufacturer sent a slab which was only 3, 4 or 6 months made he could sell it more cheaply than a manufacturer who was going to keep it 12 months in stock. If they worked out the price the manufacturers got per cubic foot for their stone they would find there was ample room for improvement so far as price was concerned. The specific gravity per ton would tell them how much was cement and how much granite chippings. They had to deal with stone as made at the present time by manufacturers, and they wanted to get a proper specification to which all the manufacturers should make their slabs. His tests were dry tests and not wet tests. Mr. Willis was anxious as to the number of voids in the slabs. They must take away the quantity of cement used in the slab from the 42 per cent. The tests were both machine-made flags of 24 in. wide. The specification distinctly stated that the size of the slab should be 2 ft. by 2 ft., but there were many cases where they must use an 18-in. slab. Mr. Newton had mentioned that in London they preferred a natural to an artificial stone. This was an artificial stone paper. Of course there were cases where a natural stone was better. He always called an artificial stone unsympathetic, and there was no doubt if they walked a mile or two on artificial stone they were more tired than on a York paving. The question of relaying the slabs had been mentioned, but how often did that occur? If it were done by statutory companies they had to pay for all the slabs they broke. The gradient, he fancied, should be 1 in 30. Mr. Picton referred to 1 in 20, but that was a very high gradient. Mr. Pickering and Mr. MacBrair mentioned hand-made slabs. The manufacturers of machine-made would claim that their slabs were better, but he wanted the Council to decide for themselves which was the best to apply, so that everybody could tender on the same specification.

INSTITUTION OF CIVIL ENGINEERS

(Manchester Association of Students).

THE MANUFACTURE AND TESTING OF PORTLAND CEMENT.

Paper by MR. J. G. BAXTER, F.C.S.

"The Manufacture and Testing of Portland Cement" formed the subject of a lecture delivered before the above Association recently by Mr. J. G. Baxter, F.C.S., at which Col. H. T. Crook, M.Inst.C.E., presided. We make the following extract:—

Quality of Cement.—Now as to the use of Portland cement; in the first place, and most important, see that you get pure Portland cement, complying in all respects with the requirements of the British Standard Specification. All natural and slag cements should be absolutely barred, there is not sufficient difference in the price to warrant the use of these cements, especially when the strength is taken into account, for the ordinary Belgian natural cement, although the analysis may show almost the same as the Portland cement, is an entirely different thing. It is made by taking pieces of rock varying from about 65 per cent. carbonate of calcium to 82 per cent., putting these without any preliminary mixing in a lime kiln with coke and burning it, not even to clinker in the majority of cases, but only to a sort of hydraulic lime, drawing it from the kilns, putting on it a little water, and allowing it to stand in sheds for several weeks, after which it is ground, and then, I am sorry to say, gets on the market, in many cases as *Best Portland Cement*. Of course, from the materials used, a perfectly sound Portland cement could be made—but not like that. As to the slag cements, they are generally mixtures of blast-furnace slag ground with lime in certain proportions. Sometimes the slag has been treated in certain patented ways to alter its nature slightly, and to get rid of objectionable constituents, but it is obvious that such a material can never hope to be like a real Portland cement for strength and reliability. Here, again, by properly selecting certain kinds of slag and going through the usual processes after the necessary addition of limestone, a true Portland cement can be made, although, perhaps, not of the best quality.

Setting Time.—Next in importance to the quality of cement is the question of setting time—always have a cement with as slow a setting time, of course within reason, as you can manage with, as you will then, in the ordinary way, get better results. There is practically no difference in the strength of concrete made from quick and slow setting cements after less than 48 hours, as the following experiment will show. Bars of concrete 3 ft. long with a 6 in. by 6 in. section were made of 5 to 1 concrete from three lots of cement, 1 quick, 1 medium and 1 slow, setting otherwise the same, and they were broken as before described after 24 and 48 hours. In no case was there any appreciable difference. If for any particular purpose you want a quick setting cement, do not have it quicker than you can avoid, and get it into place as quickly as possible, as if it is worked about too long it will become slow setting in the work, if not altogether useless. I came across a case only the other day where a certain user wanted to remove his moulds almost as soon as he had deposited his concrete, and insisted on a very quick setting cement; this was sent, and then he asked what was meant by it, as the concrete would not set in less than 24 hours, and not very well then. Of course, he had worked through the initial set of the cement and had not known it. This sort of thing is the cause of a very large proportion of unsatisfactory concrete work, and, no matter how good all the ingredients may be,

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if the cement is too quick setting it is always liable to happen. Choose the cleanest possible aggregate. Do not have dirty material, or weak concrete will result, and do not have any large proportion of soluble salts in it, or the water, or you will have trouble by efflorescence in the finished work. Thus, if you want to do concrete work during cold weather, and add salt to the water to lower the freezing point, do not be surprised and blame the cement when efflorescence appears.

Proportioning.—Proportion the cement, aggregate, and water very carefully, and see that the proportion is strictly adhered to; on large jobs it pays to give a good deal of attention to this point. It sounds almost incredible, but cases have occurred, when mixing in a machine, of the batch being mixed and deposited without the cement being put in, or the proportion of cement, through carelessness or bad proportioning, has been ridiculously small; bad concrete results, the cement is blamed. Always mix the cement and aggregate well before adding the water, and mix it better still after it has been added. A good rule when mixing is to mix it what is considered enough, and give it another turn for luck, so to speak. If the work in hand warrants a mixing machine, by all means have one, and see that it is used intelligently.

Some Dont's.—Do not, when you receive the cement, shoot it out of the sacks into heaps or insist on cement being turned at the works with a view to improving it. Present-day cement does not require this, and is not improved by so doing.

Satisfy yourself that it conforms to the British Standard Specification, when it will be good enough for anything; if it is, use it as soon as you can. If it is not, do not have it.

Do not store cement in a damp place or keep it longer than can be avoided; if the store is damp it will deteriorate.

The only way to keep cement in good condition for any length of time is in large deep heaps in a dry place or in properly made bins, and this is best done at the factory.

Do not waste any time getting concrete into place after water has been added, especially in hot weather, and if you are not able to get the whole batch into position before it begins to set do not use what is left, except as an aggregate—it may be all right, but possibly it will not be.

Do not mix very wet aggregate with cement and then allow it to stand a long time before gauging.

Do not take down moulds or forms sooner than is absolutely necessary.

Do not do any concrete work when it is freezing, if it can possibly be avoided; but, if not, get the work done as quickly as possible and use warm water for gauging, and if the aggregate can be slightly warmed so much the better; and, finally, do not, if the cement has complied with the requirements of the British Standard Specification, and the setting time is about right, blame it if anything goes wrong, in ninety-nine cases out of a hundred it is something else.

ARMOUR CIVIL ENGINEERING SOCIETY, CHICAGO.

REINFORCED CONCRETE DESIGN.

Paper by MR. ERNEST McCULLOUGH, C.E.

Tenders without Specifications.—In a paper read before the members of the Armour Civil Engineering Society at a meeting held in Chicago recently, Mr. Ernest McCullough, of the North-Western Expanded Metal Company, spoke as one of the large manufacturers of reinforcing material against the practice of inviting tenders for reinforced concrete structures without ample specifications which would ensure an adequate factor of safety. He gave it as his opinion that 95 per cent. of the buildings designed in reinforced concrete to-day were designed with the benefit of the manufacturer of reinforcing material in mind rather than with the benefit to the owner as a paramount consideration. Furthermore, he believed that not 5 per cent. of the reinforced concrete buildings were designed in the offices of the men whose names appeared upon the plans. The reason was not far to seek. The average architect did not have calls enough for that class of structure, and therefore did not attempt to design the reinforced concrete work. This custom he denounced in strong terms.

Dangerous Points.—Under the pressure of strong competition it was unlikely that the best interests of the purchaser were served by such a course, for though it might be contended that the manufacturers of reinforced concrete understood the quality and resisting properties of the material better than the architect and engineer, to whom it was often a new and untried method of construction, the temptation to reduce sections to a dangerous point so as to secure the contract must be productive of bad results. In most cases the manufacturers had to make their own designs, often under great pressure as regards time, so that it was not surprising that failures occurred, which went a long way to discredit reinforced concrete construction. A great deal had yet to be learned concerning the correct methods of designing and erecting structures of this kind, and until there was sufficient pressure to induce architects and engineers to prepare plans, complete in every detail, as they would of other structures, much unsound work would be executed. "It is a miserable system, but there is no hope of getting away from it. The only thing we can do is to teach men how to write proper specifications so the owner will be protected and so the honest manufacturers will be protected against men who will skin to save a dollar."

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

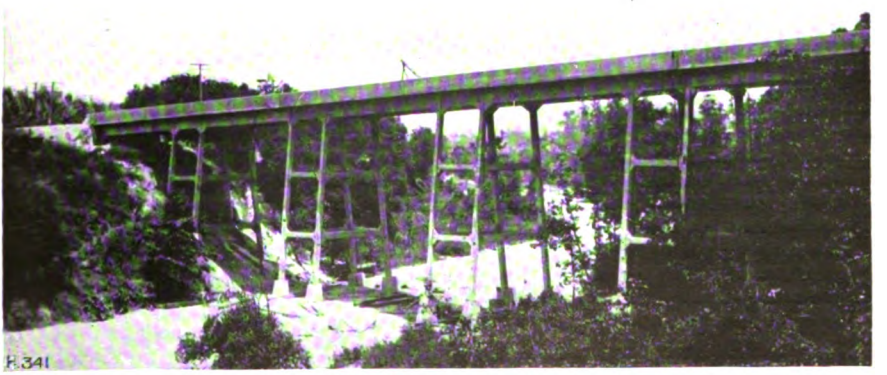
CONCRETE CONSTRUCTION OF THE LINDA VISTA BRIDGE, LOS ANGELES.

THERE has just been completed in Pasadena, California, spanning the Arroyo Seco, a new reinforced concrete bridge that is both novel and interesting, and one that marks a change in the conception and use of this material for bridge work. The prevailing idea of the use of concrete for bridge building has been that of low, short girder spans of some form of arch construction, which is, however, expensive, especially for long and high spans, and on account of its high initial cost, cheaper materials are frequently employed.

The structure was to be four hundred feet long with a 20 ft. roadway designed to carry a twenty-ton roller, and at an elevation some 65 ft. above the bed of the river. After a careful study of the bridge site and trying several schemes, and as cost was to be one of the main factors, they finally adopted the viaduct type of construction, using five tower and six girder spans. This arrangement spanned the active bed of the stream best and gave a uniform panel spacing of 17 ft. 3 in. throughout the length of the bridge, using one panel to each tower bent, and three panels for each girder span. Then they had girders 51 ft. 9 in. long supported by towers 17 ft. 3 in. by 20 ft. at the top, the tower columns having a batter of one in ten and in the transverse direction of the bridge.

Although the Arroyo Seco, as its name implies, is a dry stream nine months in the year, during the rainy season there are periods when a large volume of water, at times 6 ft. deep, with considerable velocity, has to be taken care of. A reinforced concrete bridge is one that is built for all time, and so it was necessary to carry the foundations of this bridge deep enough to preclude the possibility of a remote chance of their being undermined. In view of the fact that this stream carries but little drift, it was feasible to use isolated pier footings under the towers. These footings extended from a level of some 8 ft. above the lowest point in the river bed to from 10 to 16 ft. below this point. They are 6 ft. square at the bottom and 3 ft. square on top, there being four to each tower, or one for each column.

On excavating for these footings considerable water was encountered, being the underflow of the stream, and on two of the central towers the contractors were



LINDA VISTA REINFORCED CONCRETE BRIDGE, LOS ANGELES.

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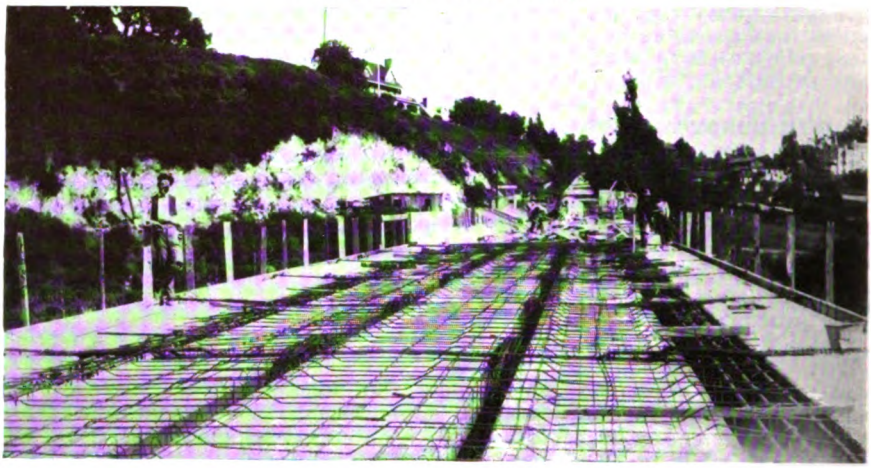
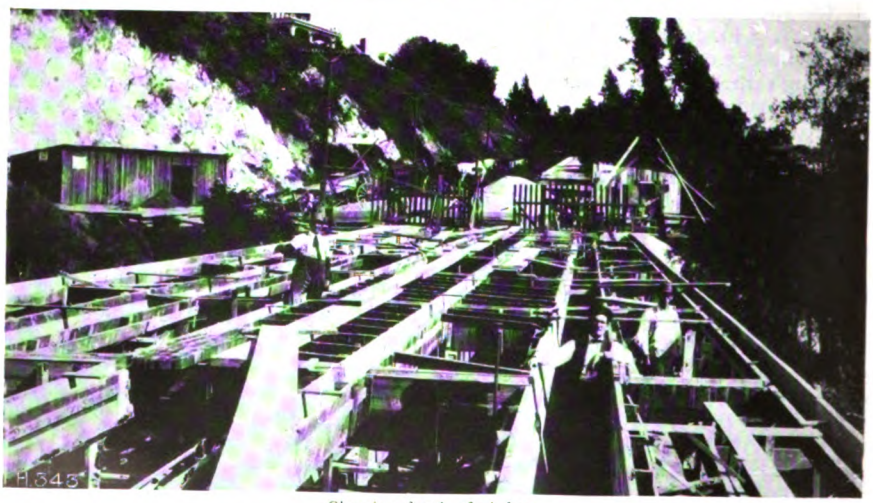
obliged to pump day and night to keep down the water level. Even then it was not possible to entirely pump it dry with the available plant, and it became necessary to deposit concrete under water. This was done with a long tube with a hopper at the upper end, which permits of placing the concrete in mass on the bottom of the

Showing reinforcement of roadway.





Showing depth of girders.

LINDA VISTA REINFORCED CONCRETE BRIDGE, LOS ANGELES.

excavation without the aggregate being separated and the cement washed out by passing through the water. The work of putting in these pier footings was pushed rapidly and concrete deposited continuously in order to get above the water level and was perfectly successful. All of the footings for the three central towers were completed before any of the superstructure was commenced, as the winter season was at hand and the contractors were anxious to get above high water with the work as soon as possible.

As intimated, the towers consisted of four columns each. These columns are 18 in. square and reinforced with eight 1¼ in. round steel bars extending into the pier footings to within 1 ft. of their base. Nearly all the columns are over 50 ft. long, and have longitudinal and transverse struts framing into their third points to stiffen them. The struts vary in size from 10 × 18 in. to 12 × 24 in., and

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are reinforced with four 7-8th in. or four 1 in. twisted steel bars laced as a column. Large corbels on two sides of the struts, reinforced with two $\frac{3}{4}$ in. twisted steel bars, form knee braces and materially aid in producing a rigid connection.

The deck consists of a reinforced concrete slab, longitudinal stringers, transverse deck beams, and girders. The stringers are 17 ft. 3 in. long and 6 ft. on centres, with a cross section of $7 \times 19\frac{1}{2}$ in. and reinforced with four 1 in. twisted steel bars. The deck beams between the large girders have a cross section of $10 \times 25\frac{1}{2}$ in. and are reinforced with six $1\frac{1}{8}$ in. twisted steel bars. In the tower spans these transverse beams were increased to 12×30 in. to add lateral stiffness. The large girders, 51 ft.

LINDA VISTA REINFORCED CONCRETE BRIDGE, LOS ANGELES

9 in. long, extending from tower to tower, have a cross section of $16 \times 58\frac{1}{2}$ in., and are reinforced with nine $1\frac{3}{8}$ in. twisted steel bars in tension and three $1\frac{3}{8}$ in. round bars in compression. In the tower bend the longitudinal girders are the same size as the 50 ft. girders, and are reinforced with four 1 in. twisted steel bars. Corbels were used on the longitudinal girders and shear bars and stirrups were provided for all stresses. The footpath is carried by small cantilever beams on brackets at every panel point, on the outside of the large girders. The rail is a 4 in. reinforced concrete slab designed as a cantilever. The truss form of reinforcement was used throughout.

Owing to the length of this bridge, it was necessary to provide joints to take care of the expansion and contraction that take place in the concrete due to changes in temperature, and the structure, therefore, is cut entirely into at two points. The expansion joints are on the outer ends of the portion consisting of the three central towers with their two connecting girder spans, and can be seen by a close inspection of the accompanying illustration. This facilitated construction also, as it enabled the contractor to erect and complete this central portion of the bridge, remove a portion of the forms from the same and use them in turn on the west and east section, which consists of a single tower and two girder spans.

The whole structure was given a pebble dash finish of cement on the outside and the footpaths were trowelled smooth and blocked off. An 8 in. cement curb with angle guards separates the roadway from the footpaths, and galvanised iron conduits are set in this curb at stated intervals, so as to effectively drain both. The roadway was given a 2 in. asphalt wearing surface.

It will be seen from the above and from the illustrations that no attempt at ornament has been made in the design of this structure and that art was sacrificed to utility in order to eliminate extra cost, but nevertheless the bridge as completed presents a very pleasing aspect.

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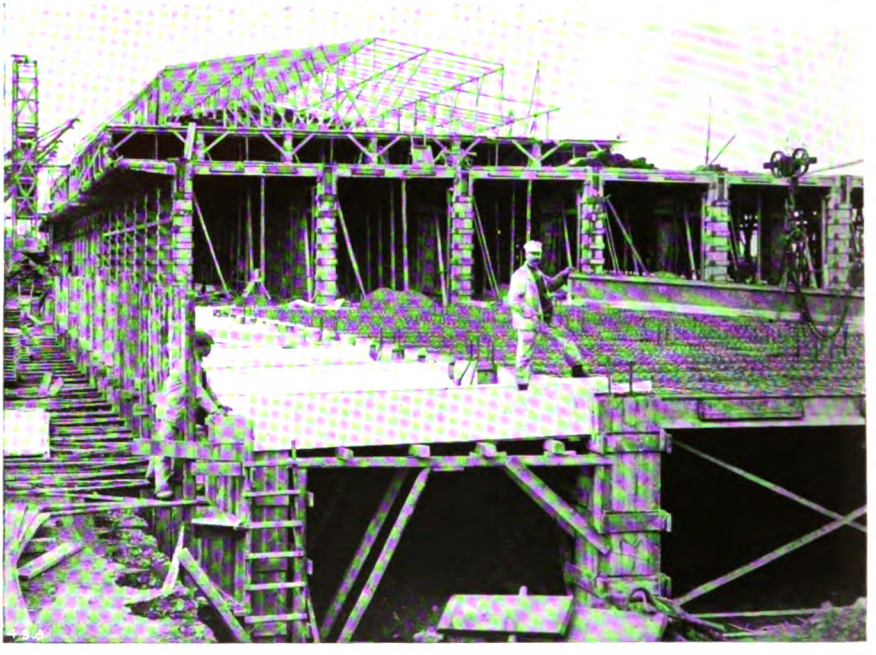
Although this bridge was designed for a 20-ton roller, there was none available when the time came to make the required test. The heaviest roller obtainable weighed 14 tons, and this was run across the bridge several times in order to thoroughly test all parts of the structure. The test was most satisfactory, and was carried out in presence of the County Surveyor, the Mayor of Pasadena and others.

In closing, it might be well to say that a competing design for this bridge was submitted and consisted of a steel viaduct some 20 ft. shorter, with wooden

Reinforced Concrete Beams being put into position.



Reinforced Concrete Beams lying ready for use,
REINFORCED CONCRETE WAREHOUSE, COPENHAGEN.

floor joist, deck and rail. Bids were called for on both plans and the lowest bid for the reinforced concrete structure was only $3,700 (£740) more than the lowest bid for the wood and steel bridge. The reinforced concrete bridge is, of course, a permanent structure with practically no cost of maintenance, and was designed to carry a load 50 per cent. greater than the wood and steel bridge. The total cost of this bridge, including engineering and inspection fees, was $22,054.67 (£4,410), and, when its length and height are kept in mind, is a fine showing for a reinforced concrete bridge, being only $1.95 (8s.) per surface foot of roadway and footpath.

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REINFORCED CONCRETE WAREHOUSE AT COPENHAGEN.

We have dealt with examples of reinforced concrete work in Denmark from time to time, and in this instance we are again presenting some illustrations of a large warehouse which has recently been completed at the Free Port of Cophenhagen.

Reinforced Concrete Warehouse, Copenhagen.
Exterior and interior views on completion.

We particularly call attention to this building as an example in which a system of reinforced concrete beams, known as the "Sterile" Beam System, has been applied by Messrs. Jensen & Schumacher, a firm of reinforced concrete specialists who may be counted among the pioneer reinforced concrete contractors in Denmark.

One of our illustrations on page 428 shows a number of these beams ready for putting into position, and another shows the beams being swung into position.

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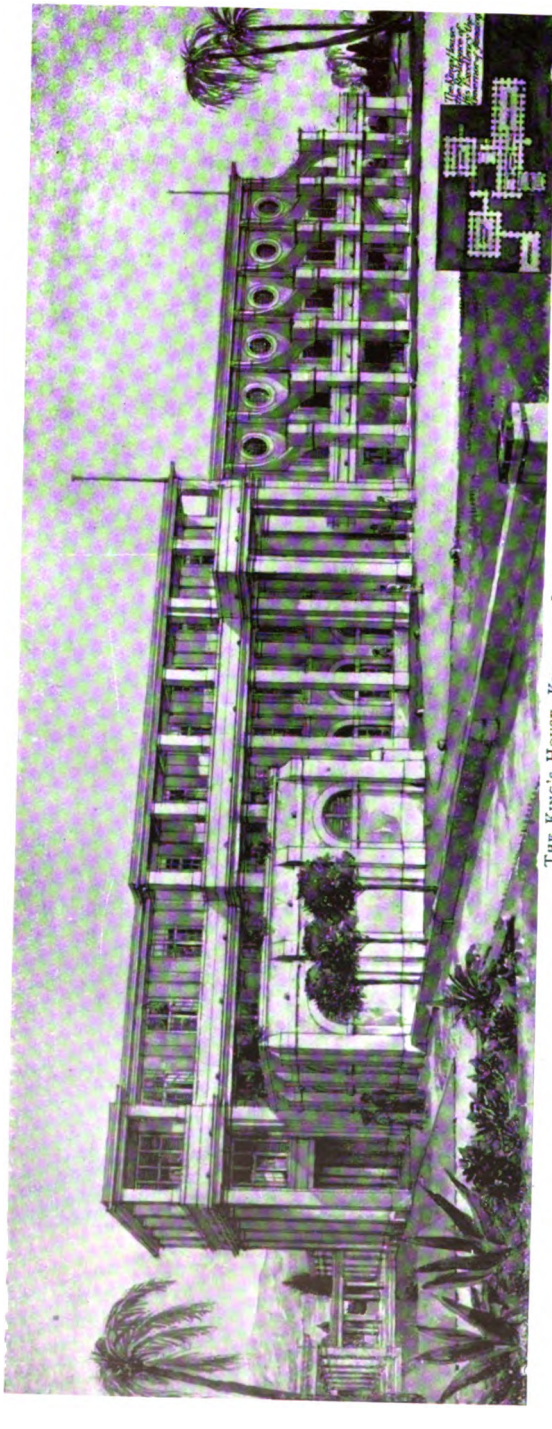

THE KING'S HOUSE, KINGSTON, JAMAICA.

The building as a whole claims attention as a good example of what can be done in reinforced concrete work where there is a straightforward plan of simple outline.

The design of the building is also to be commended, the combination of the flat surfaces of the concrete flanked by brickwork being very effective.

REINFORCED CONCRETE IN JAMAICA.

We have previously referred to the important structures to be erected at Kingston, Jamaica, in which reinforced concrete is being generally applied on account of the earthquake risk, and in a previous issue we showed a general view of a group of Government buildings.

In the present number we give the reproduction of a drawing hung at the Royal Academy, showing the new King's House, which is now almost completed. This building is intended as a residence for the Governor of Jamaica, and Messrs. Nicholson and Corlette are the architects.

It should be mentioned that this building, as far as the reinforced concrete part is concerned, has been designed on the Coignet system. Messrs. Cowlin and Son, the contractors, of Bristol, are also carrying out other new public buildings in Jamaica, such as the General Post Office and Treasury.

The King's House is composed of a ground floor, principal floor, top floor, and flat terrace roof. Each floor measures about 17,000 sq. ft. in area, including a large swimming bath and various balconies and verandahs.

The main feature of the work is that it is constructed in such a manner as to offer the greatest possible resistance to earthquake shocks and also to fire.

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NEW USES FOR CONCRETE

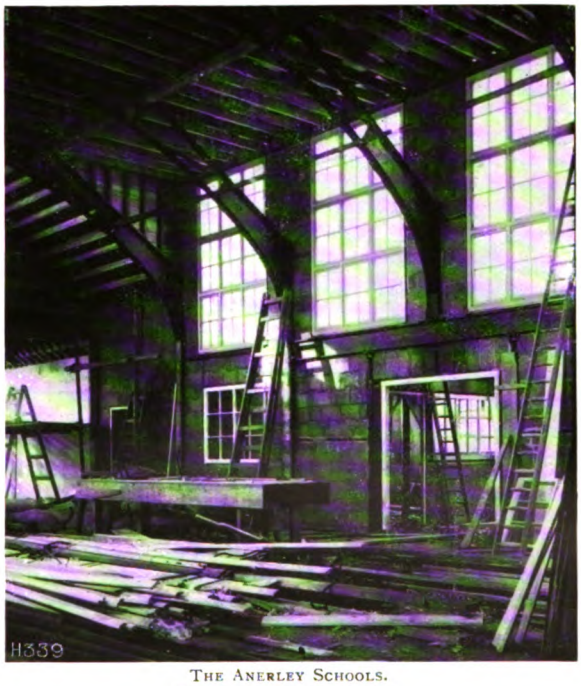
AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

CONCRETE FOR RAPID SCHOOL BUILDING.

A NEW school has been recently erected in reinforced concrete at Anerley from the design of Mr. Cecil Sharp, A.R.I.B.A., of 11 Old Queen Street, Queen Anne's Gate, S.W., who was successful in a competition instituted by the managers of the North Surrey District Schools.

The conditions of the competition were somewhat unusual, as the managers required a building to be what they termed "a temporary permanent one." This paradoxical description is due to certain provisions in the local by-laws, which only allow of the building being designated a "temporary" one, for the reason that the external and internal walls are not of sufficient thickness to comply with the by-laws for permanent structures, although as a matter of fact they are amply strong for all practical requirements, and are also fully sound-proof. In other words, although "temporary" in a legal sense, the structure had to fulfil all the requirements of a permanent one.



THE ANERLEY SCHOOLS.
View in course of erection.

The school had to be erected rapidly and was to cost as little as possible.

It will, therefore, be seen that the architect had a somewhat difficult problem to deal with, but, after due consideration of all points affected, he has been able to produce a building of a "temporary" character that can truly rank as quite permanent. It is certainly cheap and yet the quality of the workmanship and materials is good. The entire school (including the ordinary permanent structure, such as boiler house, latrines and drains, etc.) only occupied 15 weeks from start to finish, and in this short period a hot water system of heating was also installed.

The site of the building was a clay soil, over which a raft of concrete 6 in. thick was placed with 2 ft. thick concrete under the supporting stanchions and under the corners of all connecting walls. No footings or damp course were required as the surface of the concrete raft was above all surrounding ground levels.

The walls of the building were first commenced by laying down upon the concrete raft a plan of the school in steel channels, T's and angles and upon this

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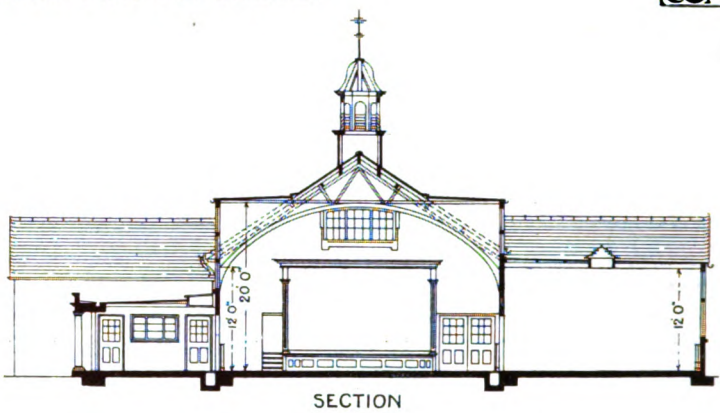
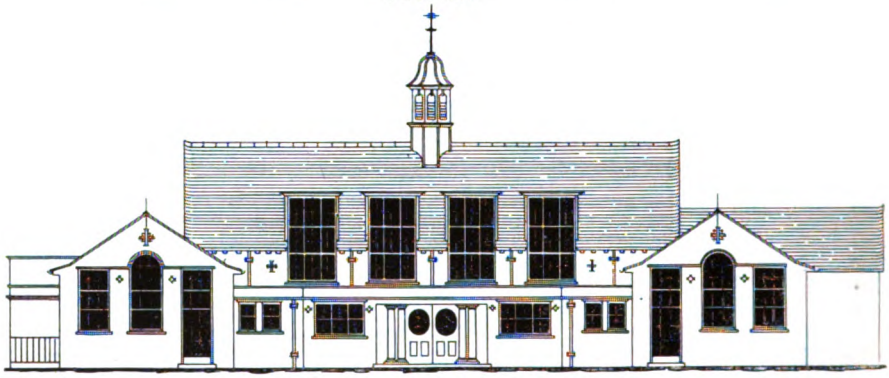
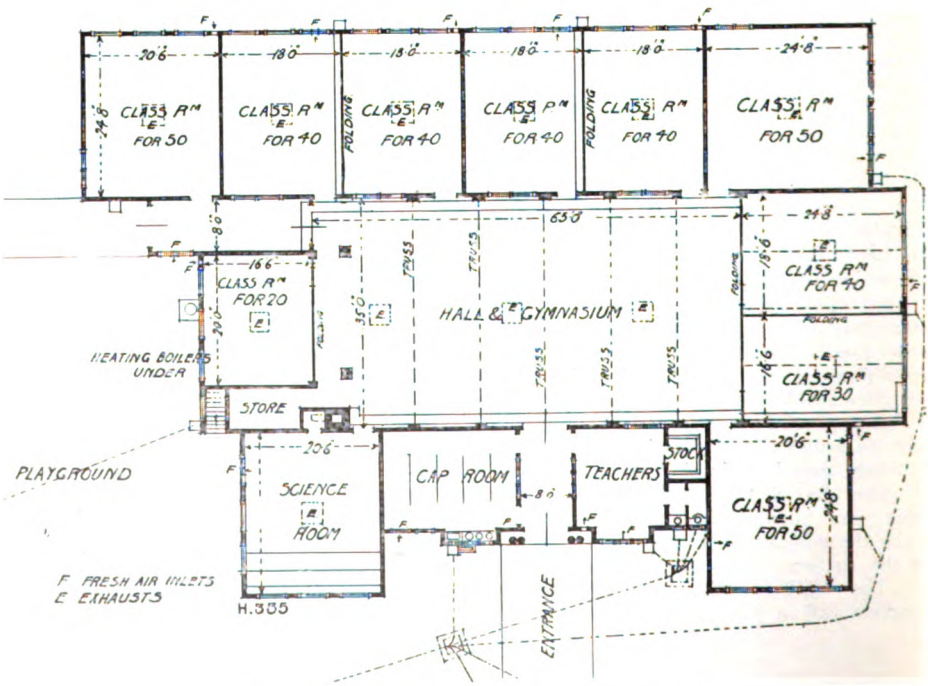


SECTION



ELEVATION

SCALE OF 10 0 10 20 30 FEET



THE ANERLEY SCHOOLS. (Plan, elevation and section.)

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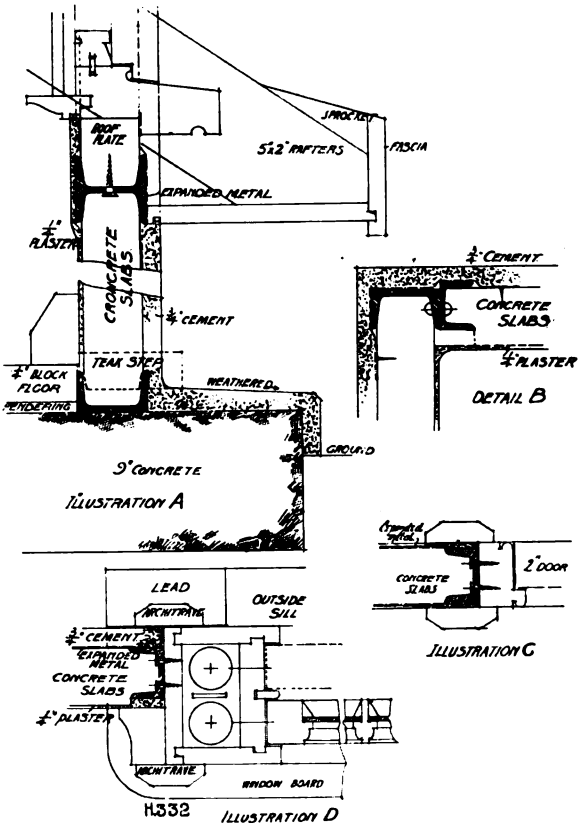
steel framed plan the angles and vertical supports of the walls were placed, also the steel stanchions to carry the main roof over the Gymnasium Hall. Steel roof-plates were bolted to these uprights to take the roof trusses, timbers, etc.

The walls internally and externally were formed by concrete slabs of a dove-tailed character, one to the other and let into the channel and steel uprights. The slabs were about 1 ft. 9 in. by 1 ft. 5 in. by 2½ in. thick. They have a groove at the edges into which liquid Portland cement and sand is forced and grouted as the blocks and slabs are built into position. Upon the inside of the walls, so constructed to cover all steel framing, expanded metal is fixed, the entire surfaces of the walls and ceilings internally being finished with a marble plaster and the external walls finished with a cement rendering ¾ in. thick (2 to 1) and roughened over with a stiff brush. All the work is absolutely rigid, of a most substantial character and perfectly weather proof.



DETAILS.

It is most important in buildings of this character that all the concrete blocks should be well seasoned, otherwise shrinkage is bound to take place in the blocks and hair cracks will appear in the cement rendering. Another very important point is the junction of the steel with the cement and with the joinery and the junction of this latter with the cement, otherwise great trouble will be experienced with rain.

As to the general arrangements of the building a plan, elevation and section are shown, and we are glad to observe that the architectural treatment of this structure is a pleasing one. Some details are presented and also photographs of the work in course of execution.

In conclusion, we would only add that this very successful building forcibly demonstrates the necessity of many of our by-laws being modified to meet the structural possibilities of the current age. To classify a building such as the one illustrated as "temporary" in order that it shall comply with some antiquated enactments does not appear to us to accord with the requirements of a nation reputed for its business capability.

Our by-laws require modernising.

REINFORCED CONCRETE RAILWAY SLEEPERS IN THE STATES.

It may be reasonably assumed that the continued use and good reports of some of the reinforced concrete railway sleepers already in the market will soon lead to their more general adoption.

As an indication of this we publish an interesting report issued by the Main-

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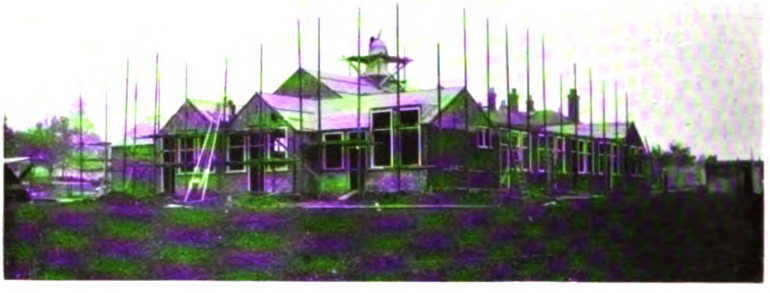
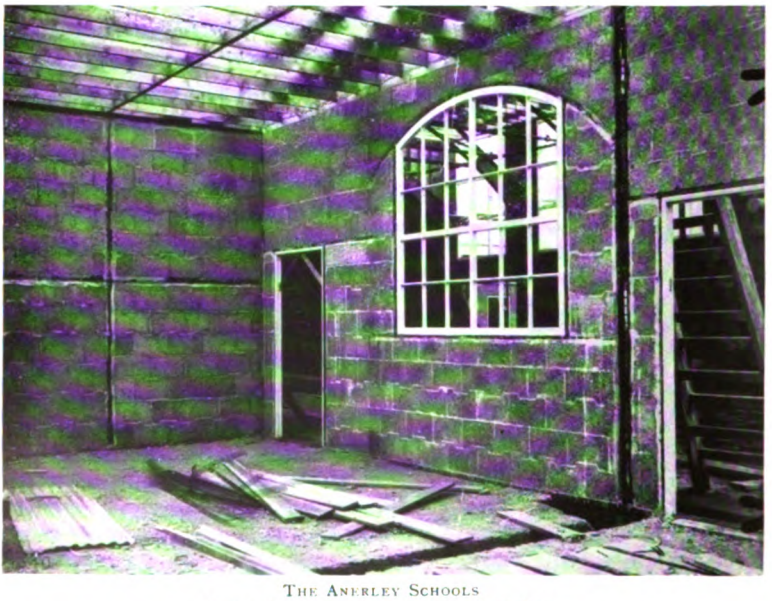
tenance of Way Department of the Galveston, Harrisburg and San Antonio Railway, U.S.A., which deals more fully with tests undertaken with what is known as the Percival concrete sleeper, a short reference to which we published last month, as also a description in our issue of March, 1906.

The sleepers tested were made of Portland cement, sharp, clean sand, and crushed sand rock, and were subjected to heavy freight and fast passenger traffic.





THE ANERLEY SCHOOLS
Views showing walls in course of erection.

One hundred sleepers were installed in October, 1905, for experimental purposes on a test track near Edgewater, Texas, U.S.A., on the main line of the Galveston branch of the above railway. The report is as follows:—

Designs.—The dimensions of the sleepers are $9\frac{1}{2}$ in. by 9 in. by 8 ft. The ends on the base are made oval for 3 ft., with an average bearing under the rail of 5 in. The centre of the sleeper is cut away for about 2 ft., making a perfect "V" shape, for the purpose of preventing centre bound track, with resultant tendency of undue stress upon the sleeper.

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The matrix contains 3 cub. ft. and 55½ cub. in. each, and is shown by water displacement. The average weight per sleeper is 445 lb. Each sleeper is reinforced with four corrugated steel bars (having 3½-in. bars near the upper face of the sleeper, and one ¾-in. bar in the base). The bars form a triangle, and are laced together with strong wire, thus making a triangular truss, the reinforcement metal weighing about 25 lb. Babbit metal sockets are properly staggered for cross-

PERCIVAL REINFORCED CONCRETE SLEEPER UNDER TRIAL.

binding of staggard spike, the babbit being lined with No. 10 wire to resist friction on threads of screw spikes. Screw spikes, ⅞-in. dia. by 10 in. long, are used, extending through a hard wood cushion, 2 in. thick by 9 in. wide by 15 in. long, the said cushion being treated with Percival "Diamond" compound.*

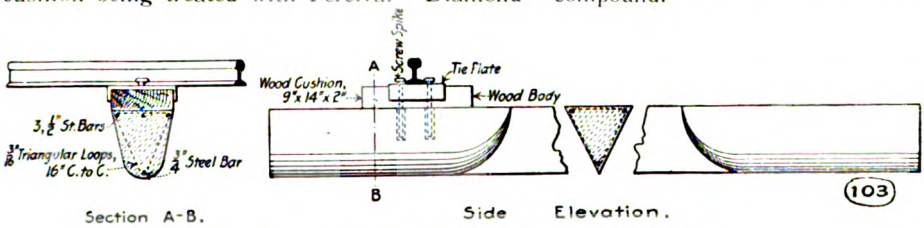

DIAGRAM SHOWING ORIGINAL DESIGN OF PERCIVAL SLEEPER.

The Composition of Concrete.†—The composition was as follows: 6 parts clean sharp sand; 2½ parts crushed sand rock, the largest piece would pass through a 1-in. mesh sieve; 6 parts Portland cement.

The concrete was hand tamped in the moulds; sleepers were manufactured under shelter, and were subjected to moisture for the first 10 days.

* Since the installation of these sleepers the inventor has adopted the use of a malleable iron lug, which permits the application of a wider base of rail when it is desired to renew present weight of rail with a heavier section; hence, in the manufacture of the concrete sleeper the proper spacing of the babbit metal sockets permits the use of the malleable lug, having different width shoulders, and which are adapted for narrow or wide base of rail, the malleable iron lugs supporting the outer edge of the screw spike head, thereby producing a more even bearing for the same.

The composition of the concrete is given as it appears in the report. The inventor writes that it should read 1 part clean sharp sand, 4 parts crushed sand rock, 1 part Portland cement.

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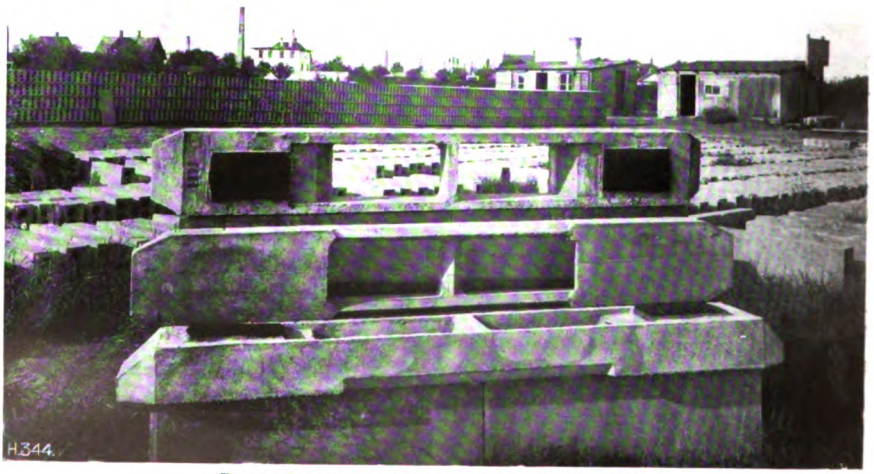
Cost.—The following are notes as to cost in United States dollars* :—

Sleepers complete	$1.8500
Freight and labour distributing	.0239
Skeletonising track...	.1832
Installing	.1532
Tota	$2.2103



DANISH REINFORCED CONCRETE RAILWAY SLEEPERS.

Details of Cost of Handling and Installation.—The following details should be of interest :—

Unloading and distributing sleepers :—		
1 hour work train service	$1.46	
6 labourers, 1 hour at $1.25 per day	.75	
1 foreman, 1 hour at $55.00 per month	.18	
		$2.39
Skeletonising track and taking out old sleepers :—		
11 day labourers, 1 day at $1.50 per day	$16.50	
1 foreman, 1/3 day at $85.00 per month	.91	
1 foreman, 1/3 day at $55.00 per month	.59	
1 timekeeper, 1/3 day at $30.00 per month	.32	
		$18.32

* A dollar equals approximately four shillings.

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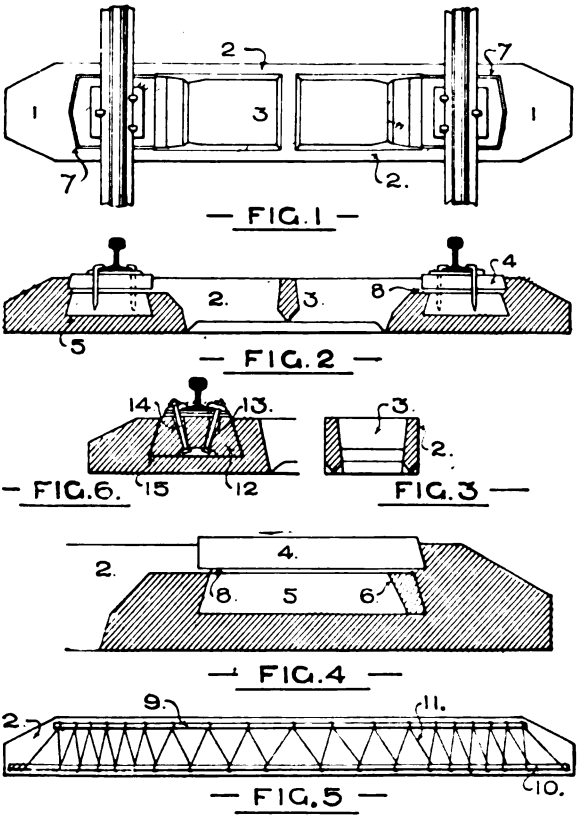
Installing 100 concrete sleepers :—		
9 labourers, 1 day at $1.50 per day	$13.50	
1 foreman, 1/3 day at $85.00 per month	.91	
1 foreman, 1/3 day at $55.00 per month	.59	
1 timekeeper, 1/3 day at . $30.00 per month	.32	
		$15.32
Resurfacing track and dressing ballast :—		
12 labourers, 1 day at $1.50 per day	$18.00	
1 foreman, 1/3 day at $85.00 per month	.91	
1 foreman, 1/3 day at $55.00 per month	.59	
1 timekeeper, 1/3 day at $30.00 per month	.33	
		$19.83
		$55.86

Location and Manner of Installation.—Sleepers were installed in the main line, near the north end of the passing track at Edgewater, Texas. Fifty of the sleepers were installed out of face and the other 50 sleepers were installed with cypress sleepers interspersed, the 50 sleepers laid out of face being laid south of the north switch at Edgewater, and the 50 sleepers interspersed with cypress sleepers being laid north of the north switch at Edgewater. Sleepers were installed under the direction of Mr. H. E. Percival, the inventor.



Danish Reinforced Concrete Railway Sleepers.

Effect of a Derailment.—On February 9th, 1907, a derailment occurred at the point wherein a 150,000-lb. capacity loaded oil car was derailed, the wheels of which passed over seventeen of the sleepers, with the result that there were seven sleepers which had their ends broken off, and ten sleepers were slightly scarred. None of the sleepers were damaged to such an extent that they had to be taken from the track. However, for appearance sake, the sleepers were renewed by the inventor.

Report of Inspection made June 5th, 1909.—On June 5th, 1909, Mr. A. V. Kellogg, Engineer Maintenance of Way, accompanied by C. A. Thanheiser, Assistant Superintendent of the Texas and New Orleans and Galveston Division, and the inventor, Mr. H. E. Percival, made an inspection of the sleepers which were installed near Edgewater, Texas, on October 22nd, 1905, the following deductions being the result of the inspection :—

Of the 50 sleepers out of face, each and every sleeper is in perfect condition —as sound as when laid—and is giving first-class service.

Of the 50 sleepers interspersed with cypress sleepers, I find that a number

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of the cypress sleepers have decayed—thereby thrusting an additional burden upon the concrete sleepers, with the following results:

Numbering the sleepers from the north end of the test track south:

The 4th concrete sleeper, east rail, which is a joint sleeper, is broken outside the rail and immediately adjacent to the wooden cushion. It has also three small scarcely perceptible cracks through the centre of the sleeper.

The 14th sleeper, which is 4 ft. from the joint, east rail, is broken on the inside of the rail adjacent to the wooden cushion.

The 27th sleeper, which is 4 ft. south of the joint, east rail, is broken on the outside of the rail in like manner to that of the 4th sleeper. This sleeper also has three small cracks between the rail.

The 34th sleeper, which is 7 ft. north of the joint, east rail, is in the same condition as the 27th sleeper.

The 37th sleeper, which is a joint sleeper, shows a slight crack in the centre.

The 38th sleeper, which is 4 ft. south of the joint, east rail, has a slightly discernible crack in the centre.

The 39th sleeper, which is 7 ft. south of the joint, east rail, has a slightly discernible crack in the centre.

All of these sleepers are in serviceable condition, and, with proper renewal of the intermediate cypress sleepers, will undoubtedly last for a good many years, the reinforcement holding the sleepers intact and preventing any tendency of spreading of the rail.

On June 15th, 1909, under the direction of C. Jensen, Roadmaster of the Galveston Branch of the Galveston, Harrisburg and San Antonio Railway, the necessary cypress sleepers (interspersed between the north fifty concrete sleepers) were renewed, and the spikes properly tightened up.

DANISH REINFORCED CONCRETE RAILWAY SLEEPERS.

In connection with the above notes on the use of reinforced concrete for railway sleepers in the United States we give some illustrations of some Danish sleepers, made by Messrs. Jensen & Shuhmacher of Copenhagen.

These sleepers are stated by the makers to have all the advantages which are necessary for their use as compared with the wooden sleepers generally employed. In the first place, they are of sufficient strength, without being too heavy. Secondly, the pressure of the rail is transferred to the sleeper without gradually crushing or wearing out the concrete. The rails are also easily and cheaply fastened to these sleepers.

Fig. 1 shows a plan of the sleeper. The reference numerals Nos. 1 indicate the concrete slab under a rail, which transfers the pressure of the rail to the ballast. Nos. 2 serve as two small connecting beams, the underside of which has splayed edges, as seen in *Fig.* 3. By this arrangement the beams can be pressed into the ballast. No. 3 is a short connecting beam arranged between the two longitudinal beams, which increases the strength of the sleeper during transit and connects the two longitudinal beams so that they can better resist side pressures.

Fig. 2 gives a longitudinal section and *Fig.* 3 a cross section of the sleeper. Wood blocks for fastening the rails are let into the slab. As experience shows that the top of such wood blocks wears out much quicker than the lower part, these blocks are divided into two scantlings (see Nos. 4 and 5, *Figs.* 2 and 4). If a new block has to be let in it is made a little shorter than the first and is fastened by a wedge (see No. 6, *Fig.* 4).

Fig. 4 shows a longitudinal section through a bearing plate, and *Fig.* 5 the steel reinforcement in a longitudinal beam of the sleeper. The steel comprises rods Nos. 9 and 10 connected by a wire trellis, No. 11.

Fig. 6 shows an alternative arrangement for fastening the rails. Here the block is made of concrete grooves (No. 13), and the bolts are fastened to the block.

We understand that a number of these sleepers are being laid down for experimental purposes on main lines and sidings in Denmark, and we hope at a later date to give particulars of the results of the tests.

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CONCRETE GARDEN SEATS.

We published in our September issue some excellent examples of concrete vases, and we now present further examples of the uses of concrete for ornamentation. The illustrations are of garden seats made entirely from concrete.

We are indebted to the *Cement Age* for our illustrations.

CONCRETE GARDEN SEATS.

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INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

SIEGWART REINFORCED CONCRETE POLES.

It was recognised by engineers in an early stage of the reinforced concrete industry that the combination of concrete and steel would prove to be particularly well suited for the manufacture of poles.

The enormous development of transmission of electric power, and the extension of tramways, telephone and telegraph lines, have produced a great demand for overhead electric cables and wires in all countries. The cost of such lines already forms a prominent part of the capital invested, and the poles for the support of the wires are to-day articles of considerable importance. The reliability of the lines is greatly dependent upon the security of the supports, and the general requirements for efficiency in this department can be classified as under :—

1. Economy in first cost.
2. Adequate strength.
3. Reliability.
4. Permanence.
5. Low cost of maintainance.

All these conditions are assured by the use of Siegwart Poles.

As to the construction of the Siegwart Poles, we have dealt with this in previous issues, the ingenious machinery with the aid of which they are fabricated being of an eminently interesting character.

We now understand that a fully equipped plant for making poles has been installed by Messrs. Siegwart, Ltd., of Caxton House, Westminster, London, S.W., at their new works at Grays (Essex), and that the company is now able to produce poles of three classes, namely: light, medium, and heavy.

What is described as a "light pole" is a pole that will comply with the Post Office regulations for telegraph and telephone purposes, whilst the medium and heavy poles also comply with the Board of Trade regulations for electric power transmission lines.

Whilst these poles are, of course, new to this country, it should be remembered that the Siegwart pole patents have been successfully utilised abroad. No less than 2,000 power transmission poles, for instance, have been installed on the Albula line, near Sargans, and quite a number of other installations are in hand.

One of the illustrations presented herewith shows the Sargans line just referred to, whilst the two other illustrations indicate a pole from the power transmission line near Ebikon and a reinforced concrete lamp standard from a set at Lucerne.

The Siegwart poles certainly claim the closest attention of our postal authorities and our telegraph, telephone, and railway companies, not only at home but also in the Colonies, for their application should mean a material saving in annual expenditure.

We trust the new poles will soon receive the attention they merit.

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SIEGWART POLES ON THE ALBULA LINE, NEAR SARGANS.
(2000 Siegwart Poles furnished.)

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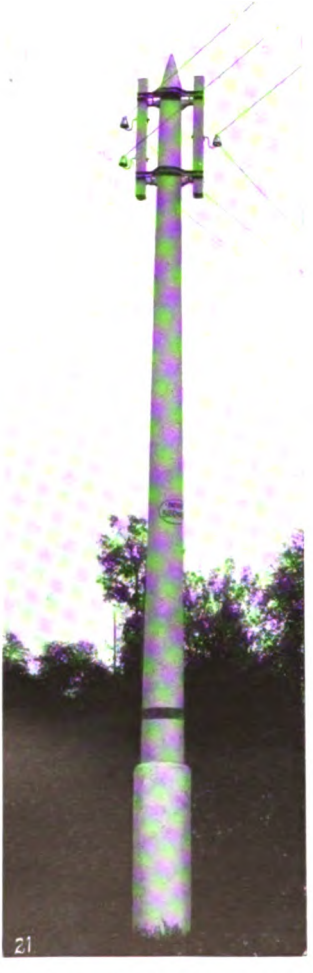
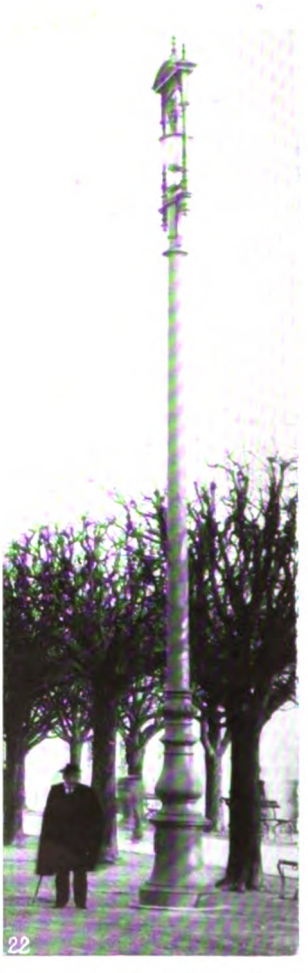
SIEGWART PIPES.

The same process of manufacture applied to the Siegwart poles lends itself admirably to the production of reinforced concrete pipes, more particularly for pipes applicable to drainage and irrigation purposes, and we understand Messrs. Siegwart, Ltd., are also taking up this problem for pipes ranging in diameter from 12 in. to 36 in. 12 in. to 36 in.

On a future occasion we will deal at length with the pipe question, but in the meantime we would now make the announcement that the representatives of the company at Cairo have just obtained a contract for eleven miles of Siegwart pipes of 12 in. diameter.



Power Transmission Poles at Ebikon.



Electric Light Standards at Lucerne.

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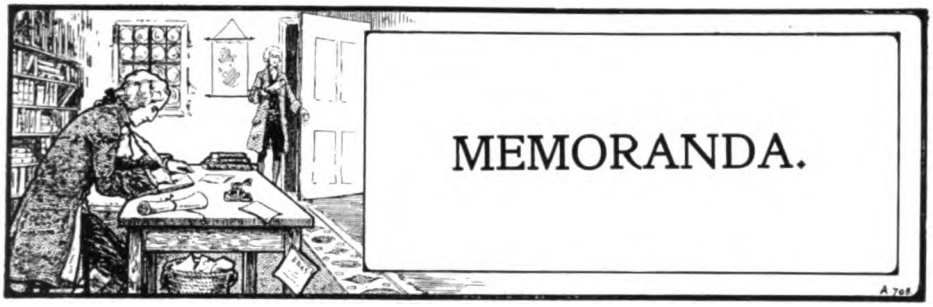

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

VISIT OF THE INSTITUTION OF MUNICIPAL ENGINEERS TO THE SWANSCOMBE PORTLAND CEMENT WORKS.

On Saturday, October 16th, about 70 members of the Institution of Municipal Engineers visited the Swanscombe Works (J. B. White Bros.' branch) of the Associated Portland Cement Manufacturers (1900), Ltd. Upon arrival at Northfleet station the party were met by Messrs. H. K. G. Bamber, F.C.S., Herbert E. Brooks, J.P., and other directors and officials of the company and were conducted to the Factory Hall, where luncheon was served.

In receiving the visitors Mr. Herbert E. Brooks said:

He welcomed them to a works which manufactured one of the greatest constructional elements in the world. Talking some years ago with Mr. H. E. Jones (Chairman of the Commercial Gas Company), that gentleman somewhat surprised him by making the statement that in his opinion Bessemer steel and Portland cement were the two most important inventions of the nineteenth century, and, of course, he felt very much flattered. The more one saw of reinforced concrete construction to-day the more one recognised the truth of that remark; but, of course, it was not necessary for him to say anything on construction to a body of gentlemen like themselves.

Mr. Brooks went on to say that he was glad to see the men who were in charge of municipal work which was likely to develop in importance as the years went on, making themselves acquainted with the manufacture of cement. They were at that moment almost within a stone's throw of the cradle of the Portland cement industry. They were within a few yards of the old Robins Works, where some of the oldest cement kilns in existence still stood; they were not, of course, using them to-day, but were keeping them as curiosities—just as early examples of the locomotive were kept. He had been thinking that morning what dimensions the cement trade of the world had already reached; he had no reliable statistics, but with the knowledge at his disposal he did not think he was far wrong if he said that the annual production of cement in the world to-day was somewhere between 20 and 25 million tons. That was a very large quantity, but thanks were due to the development of modern mechanical science. They would see at the works the advanced state of cement manufacture to-day as compared to the old days when they worked entirely by rule of thumb and their methods were empirical.

Mr. Henry C. Adams, A.M.Inst.C.E., A.M.I.Mech.E., responding on behalf of the visitors, said:

He had been selected for the privilege of thanking the hosts for the kind invitation to them to see the works, and for entertaining them to lunch. He must also thank Mr. Brooks for so kindly taking the chair that day. It was evident the Company knew how to do things well, and when they went round the works they would see that they knew how to make Portland cement. He had been privileged to see these works before and knew how from one end to the other great care was taken so that the product was a matter for marvel, nothing was lost sight of, and every advantage was taken of the advanced scientific knowledge of the present day. Most of them knew that difficulties did occasionally arise in practical work, good sand was not always obtainable except at a prohibitive cost, and there were different brands of cement on the market which were not all that could be desired, but if they had any work which went wrong, if they were using the cement of that Company, and they sent samples of the defective work to them, they would be only too pleased to make a complete examination of it, and point out where the difficulty arose.

In going round the works they would see much that was interesting; but one thing that particularly impressed him before was the hydrating apparatus, which he believed was designed by one of the

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managing directors of the Company (Mr. Bamber) for the purpose of regulating the setting time of cement without the use of gypsum. That was one of the greatest advances that had been made in the manufacture of cement in recent years.

They were all learning—there was always something new to learn—and he thought their thanks were due to the Company for the very great educational work they were carrying on in the cement industry. Five or ten years ago the knowledge of cement amongst the engineers of the country was very limited, now they had the advantage of technical papers explaining it in every detail, how the cement was made, how to remedy faults; in fact, the experts gave them all the information they possibly could regarding the material they had to use.

The visitors then proceeded to the Swanscombe Works, and on arrival were divided into a number of small parties, each under the guidance of one of the Company's officials, who explained the various processes.

Upon completion of the tour of inspection, which occupied several hours, the visitors returned to the Factory Hall, where tea was in readiness.

They subsequently witnessed a demonstration by experts of the gauging and testing of Portland Cement, including determinations of setting time, fineness, soundness, gauging of briquettes for tensile strength and cubes for compression and the testing of specimens.

A notable feature was the very compact hydraulic crushing machine which has recently been designed and put upon the market by the Associated Company for compression tests on 2¾ in. cubes.

GENERAL.

Iron and Steel Institute.—Mr. W. H. Walker (of Boston, U.S.A.), speaking to the members of this Institute on "The Electrolytic Theory of the Corrosion of Iron and its Applications," said that it was worthy of note that when iron was not soaked in caustic soda it rusted, notwithstanding the absence of any carbonic acid. That fact had an important bearing upon the question which had been discussed, as to whether concrete would protect iron from corrosion. Inasmuch as Portland cement, when it set or hardened, liberated a large quantity of caustic lime, which was a strong alkali, the answer to the question must be in the affirmative. Iron or steel would not corrode when embedded in concrete. But caustic lime was soluble in water, and poorly made concrete was not impervious to water. Therefore, if iron be embedded in concrete through which water at any time be allowed to percolate, the calcium hydrate would be slowly but surely dissolved and washed away, and with it would disappear the inhibiting action of the concrete, and iron embedded therein would surely rust. To ensure absolute protection of the reinforcing members of concrete construction, therefore, such concrete must be sufficiently dense and carefully made to render it practically waterproof. That was not an impossible condition.

Association of Engineers-in-Charge.—We are pleased to note that Mr. Henry Adams, M.Inst.C.E., has been unanimously elected President of the Association of Engineers-in-Charge. In his opening address Mr. Adams referred particularly to the subject of standard notation for calculations in reinforced concrete, and mentioned the work which the Concrete Institute are doing in this respect.

The Junior Institution of Engineers.—The paper read before this institution on October 18th was entitled "The Reinforced Concrete Construction of the new General Post Office Buildings, London," by Mr. Thomas A. Watson, A.M.Inst.C.E. The building in question has been the subject of several articles in this journal, and we do not therefore propose to publish the paper, but we would mention that it was a particularly clear one, fully descriptive of the work and well illustrated. The only points which we would extract, and which we do not recall having previously given in detail, are some data regarding the concrete, which the lecturer specified was to be as follows:—For all work below ground floor level: 1 yard of ¾ ballast, ½ yard sand, and 7 cwt. cement; above the ground floor, 6 cwts. of cement. The extra 1 cwt. of cement for work below the ground floor was chiefly on account of the retaining walls, which with this extra 1 cwt. were made watertight, the necessity for a vertical damp course outside being thus avoided. All concrete was machine-mixed, batch mixers being employed. Thames ballast was used for the aggregate throughout the work, and a special screening and crushing plant was installed to separate the sand from the ballast and to break the larger stones down to the ¾ in. size specified.

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The steel had to conform to the British Standard specification, and was all bent, caulked, twisted, etc., on the site, about 3,000 tons being used in the work.

Further, we should also mention that the steel for reinforcement was obtained from the Whitehead Iron and Steel Co., Ltd., Tredegar, Mon., and that the cement used was the Hilton Anderson brand, manufactured by the Associated Portland Cement Manufacturers, Ltd.

Birmingham Post Office Extensions.—An extension of the existing General Post Office building in Birmingham will shortly be undertaken which is to form an addition of two storeys above the present telegraphic instrument room to provide additional office accommodation and a room on the top floor, measuring 100 ft. by 43 ft., for the new telephone equipment. This addition will be constructed of reinforced concrete, faced with brick on the street front and with glazed tiles at the rear, this method being held to involve less dead weight than steel girder construction. It is anticipated that another reinforced concrete building will be put in hand next spring, and that two further similar buildings are likely to be required in the near future. Birmingham is found to be the best locality for the purpose of centralizing telegraph stores, and the work of this department is constantly increasing.

Sea Defence Works on the South Coast.—The construction of 740 ft. of sea wall has now been completed by the borough engineer at Hastings (Mr. P. H. Palmer, M.Inst.C.E.), this work having been necessitated by the undermining action of the sea. The foundations are taken down 2 ft. into the rock; the total height of the wall is 22 ft. and the thickness is 5 ft. 6 in. The facing of the wall is composed of concrete blocks fronted with basalt spalls, each measuring 2 cubic ft., this size having been adopted in order to permit easy handling by the labour of "the unemployed." With the exception of a steam pump no machinery was used, and notwithstanding this fact a saving of over £500 was effected on the estimated cost of £5,287. In conjunction with this work a new concrete groyne 220 ft. long, 18 in. above high water and 6 ft. wide at the base has been erected.

Reinforced Concrete Water Tower.—At a recent meeting of the Committee of Management of Down District Asylum at Downpatrick it was decided to accept the tender of Mr. R. D. Pollock, Bangor, Co. Down, at £2,033 for the construction of waterworks in connection with the asylum. At the asylum a water tower with tank is to be constructed, reinforced on the expanded metal system. This water tower will supply the existing water tanks by gravitation. A ground level concrete reservoir reinforced is also to be made for the purpose of storage for fire extinction, and can be utilised in case of emergencies for domestic supply.

A Reinforced Concrete Water Tank.—A reinforced water-tank, 30 ft. in inside diameter and 90 ft. high, similar to the ordinary type of steel stand-pipe which is of the same diameter from the ground upwards, has been built by the Cananea, Yaqui River, and Pacific Railroad at Empalme (Mex.). The foundation, according to the *Railroad Age Gazette*, is octagonal, with a minimum diameter of 38 ft., is 5 ft. 3 in. thick, and rests on 97 "Simplex" piles, 3 ft. 6 in. on the centres. The wall is 10 in. thick at the bottom; but for a height of 4 ft. above the floor, the thickness is 18 in. in order to make an efficient joint with the floor. The shell decreases to a minimum of 5 in. at the top. It is reinforced horizontally and vertically with corrugated bars in two circles, $2\frac{1}{2}$ in. apart at the bottom and 2 in. at the top; one circle stopping 14 ft. 4 in. from the top, the other continuing in the middle of the wall. The vertical rods are $\frac{1}{2}$ in. square, set staggered in the two circles and $10\frac{1}{2}$ in. apart; making 55 in each circle. The horizontal bars vary from $\frac{3}{4}$ in. to $\frac{3}{8}$ in. square from the bottom to the top of the tank; the spacing depending on the depth of water. The minimum spacing of the $\frac{3}{4}$-in. bars is $2\frac{3}{8}$ in. on the centres. The floor is a 9-in. layer of concrete over the foundation slab, and is reinforced with $\frac{1}{4}$-in. rods, 8 in. on the centres in both directions. The wall and floor are made of 1 to 2 to $3\frac{1}{2}$ concrete, with $\frac{3}{4}$-in. broken stone; while a 1 to 3 to 6 mixture was used in the foundation. A manhole is built into the lower 4-ft. ring. The tank has been kept filled to within 4 in. of the top.

Glasgow Harbour Works.—The construction of the quay walls at Yorkhill was entrusted to Messrs. Robert McAlpine and Sons, Glasgow, but the dredging out of the basins and quays has been executed by the trustees' own plant. Messrs. McAlpine's contract embraced quay walls on monolith foundations, ordinary quay walls, and

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timber and ferro-concrete wharfing. The monoliths generally were 30 ft. in length by 24 ft. in breadth, with one longitudinal and two cross walls, forming six wells, each 5 ft. 9 in. by 7 ft. 3 in., in which the excavating grabs worked. The height of the monolith was 34 ft. 8 in., 3 ft. being composed of a wooden shoe, and the remainder of concrete blocks 3 ft. 2 in. thick, built in courses one above the other, and breaking bond. The shoe was set in a trench at a level of 26 ft. below cope level. Between every two monoliths there is a space 4 ft. in width, and in order to make the joint secure sheet piling was driven at back and front, and the enclosed space was then dug out by grabs and filled up solid with concrete. At curved corners the monoliths are triangular in form and rounded on the face, and in such cases the shoes had to be built of steel plates and angles. In all 61 monoliths were put down. Sinking had to be assisted by piling on cast-iron weights, the loads ranging from about 400 to 1,000 tons. The length of wall founded on monoliths is about 2,063 ft.

The superstructure, 26 ft. in height to the surface of the granite coping, extends along the top of the monoliths, and is built of rubble masonry with a facing of vitrified blue bricks backed with red clay bricks. Where a hard foundation of boulder clay or rock was within reach an ordinary quay wall was built in open trench, the upper part of which was cut with slopes of 1½ to 1, and the lower portion with vertical sides, strongly timbered. The ordinary wall is 935 ft. long, and the general height from foundation to cope is about 53 ft. The timber wharf is 300 ft. in length by 30 ft. in width, aid forms the south side of the east basin. It has three rows of main piles. between the centre piles sheet piling 12 in. thick was driven, this wharf being held back to Kelvinhaugh Wharf by tie rods.

A reinforced concrete wharf forms the east end of the east basin, 120 ft. in length along the cope, and 160 ft. along the back. It is the first example of this class of work on the Clyde, and has been constructed as an experiment in view of other works which are now proposed. The structure has been executed on the "Hennebique" system.—(*Times Engineering Supplement.*)

Reinforced Concrete in Auckland, New Zealand.—We understand that a considerable amount of reinforced concrete work is now being executed to the instructions of the City Council of Auckland, for which body Mr. Walter E. Bush, Assoc.M.Inst.C.E., acts as technical advisor.

Besides the 320 ft. span Grafton Bridge, previously referred to, and for which the Ferro-Concrete Co. of Australasia are the contractors, an extensive reservoir, intended to hold 3,000,000 gallons, is being constructed. Further, a large intercepting sewer across one of the shallow bays of Auckland Harbour and some storage tanks, with a capacity of 9,000,000 gallons, are about to be constructed in reinforced concrete.

The development of the use of reinforced concrete in New Zealand is certainly an interesting factor in the annals of the Empire's structural works.

Reinforced Concrete in Shanghai.—We hear that a considerable amount of reinforced concrete work is now in course of execution at Shanghai, notably from the designs of Messrs. Davies & Thomas. Besides the new Telephone Exchange Buildings, which are entirely of reinforced concrete and which were completed in 1908, there is the new Astor House Hotel, a five-storey building of reinforced concrete, and a new wharf, 1,180 ft. long by 200 ft. wide, of the same material. Several Godowns are also in course of construction, all of reinforced concrete, involving altogether an expenditure of close upon a quarter of a million sterling.

Reinforced Concrete Piers.—During the past eight or ten years a good many examples of concrete-sheathed timber pile construction have been built by the State Harbour Commissioners of San Francisco, the object being to obviate the rapid destruction of unprotected timber by the teredo, which is very active in the Bay of San Francisco. Ordinary wooden piles, driven to secure the requisite bearing, were provided with an outer casing of concrete formed in cylindrical moulds placed over the piles after driving. It now appears that the present condition of piers built on this type of substructure is far from satisfactory, and that in consequence, reinforced concrete cylinder piers are being adopted in the important scheme of harbour improvements now in progress.—(*Engineering.*)

Mr. Chiozza Money, M.P., writing to one of the daily papers, gives an extract from a letter of a correspondent in the course of which he says: "From time to time I have shown how reinforced concrete has made its way. For modern buildings it

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presents peculiar advantages. The work is rapid and the work is good. Reinforced concrete withstands the effects of heat; it simplifies building, and it enables tall buildings to be erected with comparatively thin walls, thus saving space and economising rent." We are glad to see a letter quoted which so correctly and tersely summarises some of the principal features of the new material.

Northern Polytechnic Institute and Reinforced Concrete.—We are pleased to note that a course of lectures on reinforced concrete is being given at the Northern Polytechnic Institute, Holloway Road, N., by Mr. Oscar Faber, B.Sc., A.C.G.I. The lectures are held on Wednesdays from 7.30 to 9.30 p.m. and are supplemented by experimental work, and should be of great interest and utility to students and engineers not familiar with this method of construction. The fee for the session is 12s. 6d.

Remedy for Damp Concrete Floors.—*Work* gives the following reply to a correspondent who complained that the concrete cellar floors of two back-to-back houses are usually damp: From the particulars given it may be safely assumed that the concrete floors are improperly laid, and the division wall has no damp-course. The floors may be covered with a layer of asphalt, or the concrete may be removed, the ground excavated, and filled in with 6 in. of dry brick rubbish and 4 in. of Portland cement concrete, the latter composed of Portland cement 1 part and 3 parts fine clean ballast, and floated over with cement and washed sand 1 in. thick, the cement and sand in equal parts. The wall should have a damp-course inserted as near the level of the floor as possible, and the wall rendered in cement and sand to the height of the damp-course.

The Gunnison Irrigation Tunnel.—The formal opening by President Taft, on September 23rd, of the Gunnison Tunnel in Colorado marks the substantial completion of an important Government reclamation project. The principal feature of the undertaking was the piercing of a tunnel from the Gunnison river canyon through one of the ranges of the Rocky Mountains, about six miles, towards the valley of the Uncompahgre.

At the opening of the tunnel the Gunnison river runs through a canyon 1,800 ft. deep, with precipitous walls. The elevation of the bed of the river is about 6,000 ft. above sea level. The tunnel opens at an elevation of about 7 ft. below mean low water level of river, piercing the mountain range for 30,582 ft. on a uniform down grade of 2·02 ft. per thousand, and the waterway is continued beyond the western portal of the tunnel in a concrete-lined canal 30 ft. wide at the bottom, 83 ft. wide at the top, and calculated to maintain an average depth of 10 ft. of water.

The project has been discussed as a possibility for 20 years. The United States Government has been engaged upon it since 1905 under the National Irrigation Act of 1902. The cost of the tunnel and canal is estimated at £1,000,000, and, in addition to furnishing water for the irrigation of the 150,000 acres of fertile soil, it is expected that a large amount of power will be available for a variety of commercial and industrial purposes.

TRADE ANNOUNCEMENTS, CATALOGUES, ETC.

The British Fibro-Cement Syndicate have recently concluded contracts for delivery of one million of their slates for India and about the same quantity for South America. Their representative in South America is soliciting the Government there to exempt this article from import duties, so that being made cheaper it may be largely used for new buildings. This roofing is found very suitable for the climate there and is much appreciated.

Work in Fibro-Cement has been erected for H.M. Government at Gibraltar, Malta, Mauritius, Jamaica, Bermuda, etc., and also for a large number of buildings in this country.

The British Uralite Company (1908), Ltd.—We learn that Mr. Thomas Athey, formerly manager of Messrs. Spencer, Santo and Co., the old-established building contractors of Warwick Road, Kensington, has joined the staff of the British Uralite Company, of 16 St. Helen's Place, E.C.

The Columbian Fireproofing Company, Ltd., King William Street, E.C., have issued an artistic and well-printed pamphlet descriptive of the "Bonna" system of armoured steel and cement pipes. The position taken up by the company is that the qualities resulting from the proper combination of steel and cement render armoured cement in every way suitable for the manufacture of pipes, especially for those of large

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diameter and those which are required to resist high internal pressure. In France especially reinforced concrete has been extensively applied to the construction of pipes for the conveyance of sewage and water. Having purchased the "Bonna" system after long and careful investigation of the process and its results, the company are now introducing it with confidence in the advantages it possesses over iron or steel pipes. It is pointed out that local authorities are sometimes deterred from carrying out water supply and sewerage schemes owing to heavy initial cost, the cost of repairs owing to corrosion in iron and steel pipes, and the consequent burden on the ratepayers. On the other hand, the Bonna system, it is claimed, reduces initial cost, an installation of reinforced concrete being cheaper and equally strong; practically abolishes repairs, there being no corrosion or leaking; and consequently reduces the burden on the ratepayers. The pamphlet contains an account of the mode of manufacture of the Bonna pipe; an article by Mr. R. H. Wyrill, M.Inst.C.E., waterworks engineer of Swansea, where the company carried out a considerable installation; and a report and paper (the latter read at a meeting of municipal engineers) by Mr. A. E. Collins, M.Inst.C.E., city engineer of Norwich, where the company constructed a large rising main. The numerous reproductions from photographs assist in the elucidation of the system.

The Expanded Metal Co., Ltd., inform us that they have appointed Mr. B. J. Miller, one of their works' representatives, to succeed the late Mr. Harry Mason as their representative in Manchester and district. The Company's Manchester address has been changed to Temple Chambers, 33 Brazenose Street, Manchester.

The Improved Wood Pavement Co., Ltd., of Queen Victoria Street, E.C., have sent us an excellently illustrated catalogue dealing in a very effective manner with the different designs of their wood block flooring. Wood block flooring is specially suitable for application to concrete and reinforced concrete floors in industrial buildings, and should be more freely used than heretofore.

This company's contracts for their creosoted deal paving this year amount to over 200,000 superficial yards, and include some of the most important thoroughfares in London and the provincial towns.

"Patent Indented Bar Bulletin."—We have received the July number of this bulletin, which deals with water tower construction in different parts of the country where the Patent Indented Bar has been employed. The recently opened water tower at Cleethorpes, Grimsby, is well illustrated, and there is a good deal of interesting matter in connection with the erection of similar towers.

CONTRACTS.

The following lists of contracts recently entered into are prepared from statements sent us by the firms mentioned below:—

British Reinforced Concrete Engineering Co., Ltd.—Maesycoed schools floors; culvert at Blaenavon, South Wales; fireproof floors for Public Hall, Keighley; stores, North Wales; a warehouse on the Thames Embankment; chemical works on the Mersey; fireproof building at Aberdeen.

British Uralite Co. (1908) Ltd.—12,000 ft. of their material for Assam; 3,000 ft. for Admiralty Harbour, Dover; material for skating rinks at Doncaster and Loughborough; re-roofing radial crane house at Royal Arsenal, Woolwich; erection of a building at Pembury Waterworks for the Tunbridge Wells Corporation; 40,000 ft. for a Russian chemical works.

Cubitt Concrete Construction Co.—Swimming baths at Repton; storage and cold brine tanks, Great Western and Metropolitan Dairies, Ltd.; grand stand for Liverpool Cricket Club; Home of Refuge for Incorporated Society of Crusade of Rescue; raft under convent at Tilbury Dock; fireproof staircases at Liverpool; farm buildings, Ruthin; three bridges at Poole; floors and tank at Chilton Lodge, Hungerford.

Jos. F. Ebner.—Public buildings and King's House, Kingston, Jamaica (see illustration, page 430) (7,000 yds. super, "Ebnerite" flooring); Lowestoft schools (1,500 yds. "Ebnerite"); new premises for Messrs. Fox Bros. & Co., Wellington (2,000 yds. "Ebnerite" and terrazzo); new workhouse, Crumpsall (1,200 yds. "Ebnerite"); convent, Roehampton (wood blocks); Technical Institute, Belfast (2,000 yds. wood blocks); two schools at Croydon (3,000 yds. wood blocks); new schools Harwich (wood blocks); several new schools in South Wales (wood blocks).

Expanded Metal Co., Ltd.—Flooring in extensions to the British Museum, London; at the Central Free Library, Birmingham; the Royal Naval Hospital, Haslar; the Convent, Stillorgan, Ireland; at Messrs. Stevenson's Dye Works, Dundee; Branselwhite's Maltings, Long Melford; Convent, Roehampton; gasworks, Greenock; new stores, Castleton; Nurses' Home, Dewsbury; at the Infirmary, Macclesfield; the Hospital, Wallsend; new premises, Primrose Street, Perth; St. Vincent's Orphanage, Carlisle Place, S.W.; new schools, Bridlington; at County School, Falmouth; to tank, Landore, South Wales.

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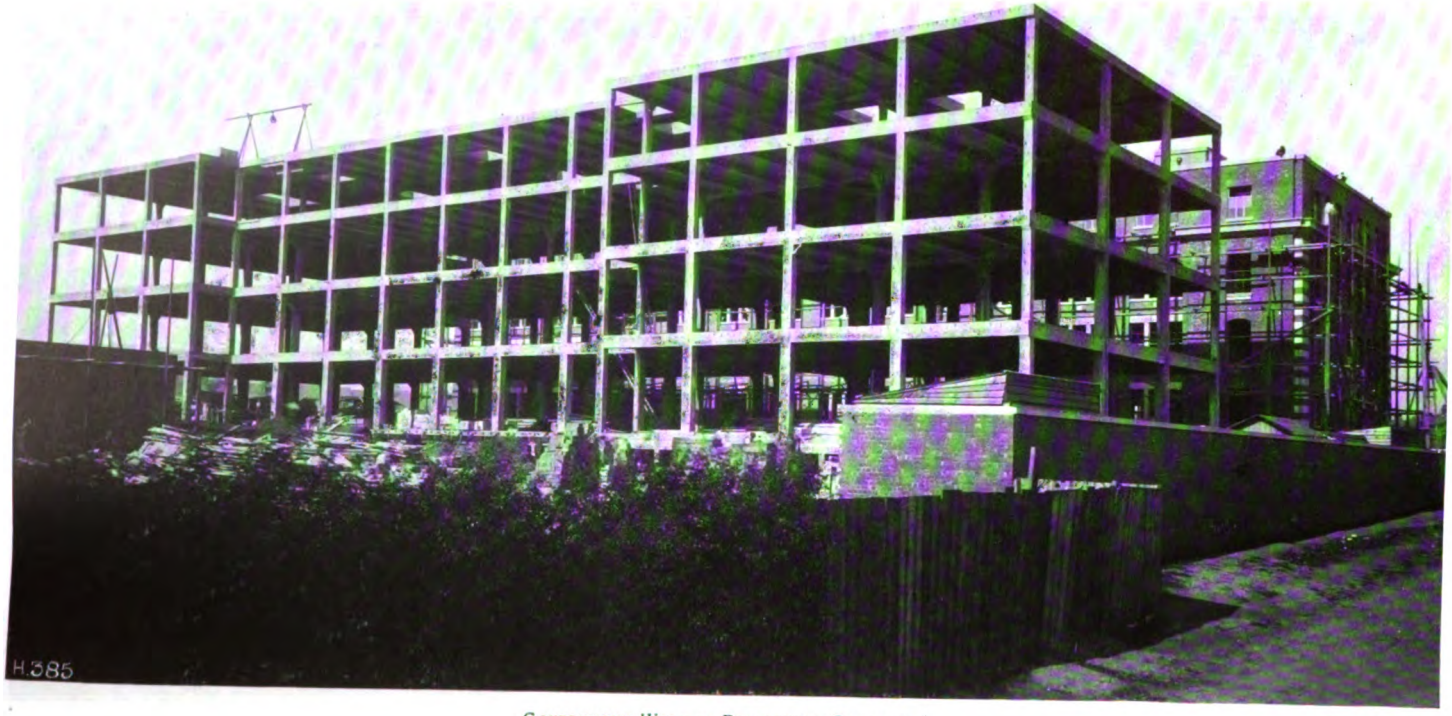

GOVERNMENT WORK IN REINFORCED CONCRETE.
The New Telegraph Stores, Birmingham.

Frontispiece.
(Opp. Contents.)

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume IV. No. 7. LONDON, DECEMBER, 1909.

EDITORIAL NOTES.

THE LOCAL GOVERNMENT BOARD AND REINFORCED CONCRETE.

WE have from time to time dealt with the difficulties local authorities encounter when applying to the Local Government Board for decision as to loan periods where reinforced concrete structures are contemplated.

Although, to our knowledge, there has been some slight improvement upon the entirely negative attitude originally adopted by this department, we are still constantly receiving complaints that for all practical purposes it is useless for the engineers of local authorities to get out schemes for reinforced concrete structures unless they are prepared to accept a loan period of approximately 10 years, as against the 30 years more generally accorded to the older forms of construction.

As we have indicated on earlier occasions, we know of instances, such as that of a reinforced concrete water tank in London, where the loan period granted was about 26 years, but such cases are unfortunately still very exceptional.

The latest complaint comes from Berwick-on-Tweed, where the Local Government Board, whilst stating that the water supply scheme proposed by the Corporation and involving a loan of about £20,000, was generally satisfactory, apparently specify that "if it is proposed to construct the reservoir in reinforced concrete they would only be able to allow a period of 10 years for the loan; whereas, if the reservoir were constructed of brick or concrete the period would be 30 years."

We are glad that publicity has been given to a specific instance such as this at Berwick-on-Tweed.

Not dozens, but hundreds, of reinforced concrete reservoirs exist in different parts of the world that have not given the slightest cause for complaint, and are in every way not only equal to, but often better than the structures of the older form, on account of their monolithic character.

The action of the Local Government Board in this case is equivalent to officially condemning reinforced concrete as a whole, for whilst up to the present we understood the practice was generally to give local engineers a "hint" from Whitehall not to approach the Local Government Board with reinforced concrete designs, or to limit the loan period without giving formal reasons, we now actually have a case where the Board's opinion of the material has been baldly stated in writing.

After the attitude taken by the Local Government Board it is, of course, difficult for its present officials to reverse their policy without some "higher

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authority" to fall back upon for the change of front. As before suggested, we would thus strongly advise that a departmental committee on reinforced concrete be constituted under the auspices of the Local Government Board. This committee should be representative not only of the Board's own officials, but also of those attached to the other large departments which are constantly using reinforced concrete; it should be representative of the various technical societies concerned, and perhaps also of some of the local authorities that have had experience in work of this character.

The sooner a departmental committee of this character is constituted the better, and the less difficult it will then be for the Local Government Board to reverse its present policy, as it must eventually do in any case.

It is well known that whilst Mr. Burns's department is handicapping the erection of the smallest structure in reinforced concrete, if undertaken by a municipality, the same Government, of which that Department forms a unit, is extensively using reinforced concrete for its Admiralty, War Office, and Post Office structures.

THE CONCRETE INSTITUTE.

THE Concrete Institute commences its second session as we go to press, and we understand that its membership, which was approximately 420 in December, 1908, has grown to no less than 840 in the intervening twelve months. In other words, the membership has just been doubled, which speaks volumes for its utility.

We are interested to observe that the first meeting of the new session was devoted to an impromptu address by one of the leading authorities on reinforced concrete from the American Continent, Mr. Richard L. Humphrey, M.Am.Soc.C.E., of Philadelphia, who is secretary to the Joint Committee on Concrete and Reinforced Concrete of the United States.

The United States is having its own troubles regarding reinforced concrete. We have dealt with the Interim Report of the Joint Committee at some length in our issue of October, and this report has now been followed by a minority report and a lengthy discussion in the American Society of Civil Engineers.

As with us, so in the United States, there are still members of the technical professions who allow legitimate caution to become mere prejudice, and prejudice to eventually become antagonism. There the purely technical aspect of the subject is further distorted by the brick and terra-cotta interests waging war against reinforced concrete in every conceivable manner whilst the steel trade are systematically opposing the introduction of the new material wherever they think their sphere may be affected by its advent. Both these interests respectively command the services of engineers and architects of high standing. Thus all we read of technical debates is not due to an effort to unravel scientific problems or benefit professional colleagues. It is all too often simply a question of brains rented for the "almighty dollar."

Mr. Humphrey, however, by his position as a Government official holding an appointment under the Geological Survey, has come before the Concrete Institute as one whose views command respect, and as these are generally favourable to the introduction of reinforced concrete when carefully designed and

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suitably constructed, his favourable impressions can be looked upon as a valuable advocacy.

We are glad that he should have had an opportunity of speaking before a suitable audience in this country, and we trust that the precedent created on this occasion by the Concrete Institute may be followed when other distinguished visitors conversant with problems relating to concrete and reinforced concrete happen to be visiting this country.

THE BATTLE OF THE POUND AND THE TON.

THE attention of our readers is invited to the suggestion made in our Memoranda of this issue.

As reinforced concrete comes into more general use, the conflict for supremacy between the ton, the cental, the kilo, and the pound is bound to become more acute.

The practice of other countries has made its impress felt in the selection of units. The kilo finds first favour among those who uphold the metric system through thick and thin. The ton, in spite of its advantages in regard to its magnitude, seems to be falling into disuse, largely on account of the dominating influence of the flood tide of American technical literature.

The *entente* with the States seems to render the word "ton" more and more ambiguous. In reading reinforced concrete literature we never seem quite sure unless we know the nationality of the writer, or the publisher's address, whether a short ton of 2,000 pounds is intended, or the long ton of 2,240 pounds avoirdupois.

The Americans, as a rule, avoid the ambiguity by expressing their stresses in pounds. The pound, however, while very useful for household requirements, is inconveniently small for the stresses on steelwork and reinforced concrete. Imagine the load on foundations being given in pounds; yet we have seen this done, and the weight ran into many millions of pounds. What a waste of time, paper, and writing while a larger unit is available!

We are reminded of a pregnant statement made by Mr. Hess, and quoted in Vol. XXIV. of *The Transactions of the American Society of Mechanical Engineers*, in a discussion on the metric system. "It is," says Mr. Hess, "very likely that no series of units can be generally satisfactory. The requirements of the various arts and sciences are far too varied for that. *The best unit, or series of units, is one that does not involve large figures.*"

Having this cardinal principle in mind, and bearing in view the hopelessness of the possibility of the various partisans of the ton, the pound, and the kilo coming to a decision in our lifetime, the *via media* proposed by Mr. Fiander Etchells in our Memoranda is worth careful consideration. Perhaps the unit of 100 pounds and of 1,000 pounds could be used until the battle of the long and the short ton be finished, or until the advocates of the metric system have converted everybody to their creed. In the meantime most busy designers should welcome the proposed abolition of superfluous noughts.

We should be glad to know the opinions of our American friends upon this English approach to their hundredweight and their half-ton. The American half-ton and the American hundredweight appear to languish, not because of any inherent defect, but because they lack a short and unambiguous title.

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The names suggested would certainly avoid ambiguity, and are short enough for common parlance.

The use of a larger unit is, of course, the first step towards the reduction of the number of figures or ciphers required to express any given load or stress in round numbers.

THE BIRKENHEAD MISHAP.

THE accident to a reinforced concrete platform of some stables in course of construction at Birkenhead is being accorded quite undue importance, more particularly if we compare this accident with the many far more serious accidents where lives are lost on buildings of ordinary every-day methods of construction.

Reinforced concrete, being looked upon as a novelty by the less well-informed members of the technical professions, and as something in the nature of good "copy" by the lay Press, it is not surprising that an accident in connection with the use of this form of construction lends itself to exaggerated comment on the slightest provocation.

As we have previously had occasion to remark, a disaster of a steel bridge involving 80 lives and £500,000 scarcely has more space given it than a reinforced concrete failure involving £300 and having no fatalities.

Far be it, however, from us to desire to present an excuse for an accident such as that which occurred at Birkenhead. Such an accident in the course of construction is obviously either due to an error in design, to bad execution, or to a premature removal of the false work. Of course, it may also be due to a combination of these factors or to a lack of proper supervision.

Accidents of this kind should in no way affect the use of reinforced concrete as a whole; but, on the other hand, they should serve as a useful warning to those who use reinforced concrete, design or execute it. For all constructional or engineering work of any moment proper precautions have to be taken, and skilled supervision is essential. Reinforced concrete, of all building materials, requires proper care and first-class supervision.

SIMPLE CONCRETE SLAB BUILDINGS.

IN our "Industrial Notes" we show illustrations of an interesting new structural method for erecting simple buildings by means of large concrete slabs. The system was designed for the purpose of obtaining buildings cheaply and quickly, and the simplicity of moulding and erection was the chief point kept in view. The idea originated with Mr. Buddicom, an estate agent in Wales, where the first specimen buildings are being erected.

It is, we understand, the first time such a method has been used in England for rural work, and the idea is to be commended on account of the facility of erection as well as its low initial cost. A not dissimilar method has been tried before for more complex town buildings, but the case here is one on somewhat different lines.

So much has been written in the lay Press regarding Mr. Edison's invention of "pouring" or "moulding" concrete houses that we are pleased to observe the initiative taken in this matter in Great Britain, for it is a matter of importance where the working of cheap farm property is concerned.

The idea as it at present stands is, of course, in its infancy, and requires development, but the kernel is sound, and the scheme ought to meet with success.

At a time when the question of small holdings is having so much consideration the principle of Mr. Buddicom's method of construction should be welcomed.

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The New Telegraph Stores, Birmingham

It affords us great pleasure to again give particulars of reinforced concrete work executed to the instructions of H.M. Office of Works. In this instance our article deals with the two blocks of the new Telegraph Stores at Birmingham, of which one has already seen completion and the other will soon be ready for occupation.—ED.

We have frequently illustrated reinforced concrete buildings that are being executed to the instructions of H.M. Office of Works for the use of the General Post Office, and on this occasion we are again referring to the new Telegraph Stores at Birmingham, of which the second block is now nearing completion.

It is customary to associate our Government departments with ultra-conservatism in matters of building construction, but H.M. Office of Works has certainly set an example in adopting modern methods of construction, and has been a pioneer in applying reinforced concrete to post office work, thereby effecting material economies in the expenditure of the State. The General Post Office at St. Martin's-le-Grand and the Western District Post Office are notable examples, whilst the Telegraph Stores now referred to, and the Money Order Office which is just being put in hand, are further instances in this direction.

Regarding the new Telegraph Stores at Birmingham, eventually there are to be five blocks of buildings of practically identical plan. The first of these has seen its completion, and was mentioned by us in our issue of March, 1908. The second block will soon be finished. Both have been erected under the supervision of H.M. Office of Works, of which Sir Henry Tanner, I.S.O., F.R.I.B.A., is the principal architect, and the general designs were by Mr. J. Rutherford, of that office.

Both blocks have been executed by the Cubitt Concrete Construction Co., which forms part of one of the largest contracting organisations in the United Kingdom—Wm. Cubitt & Sons, Ltd., of Gray's Inn Road, W.C.—and in both blocks the system of reinforcement adopted was that of the Trussed Concrete Steel Co., Ltd.

The similarity of the two blocks is such that we are showing the plans and sections of the first block and some photographs of both.

Each block comprises four floors and a roof, and measures some 203 ft. by 65 ft. at greatest width, with a height of 60 ft. The ground floor is designed

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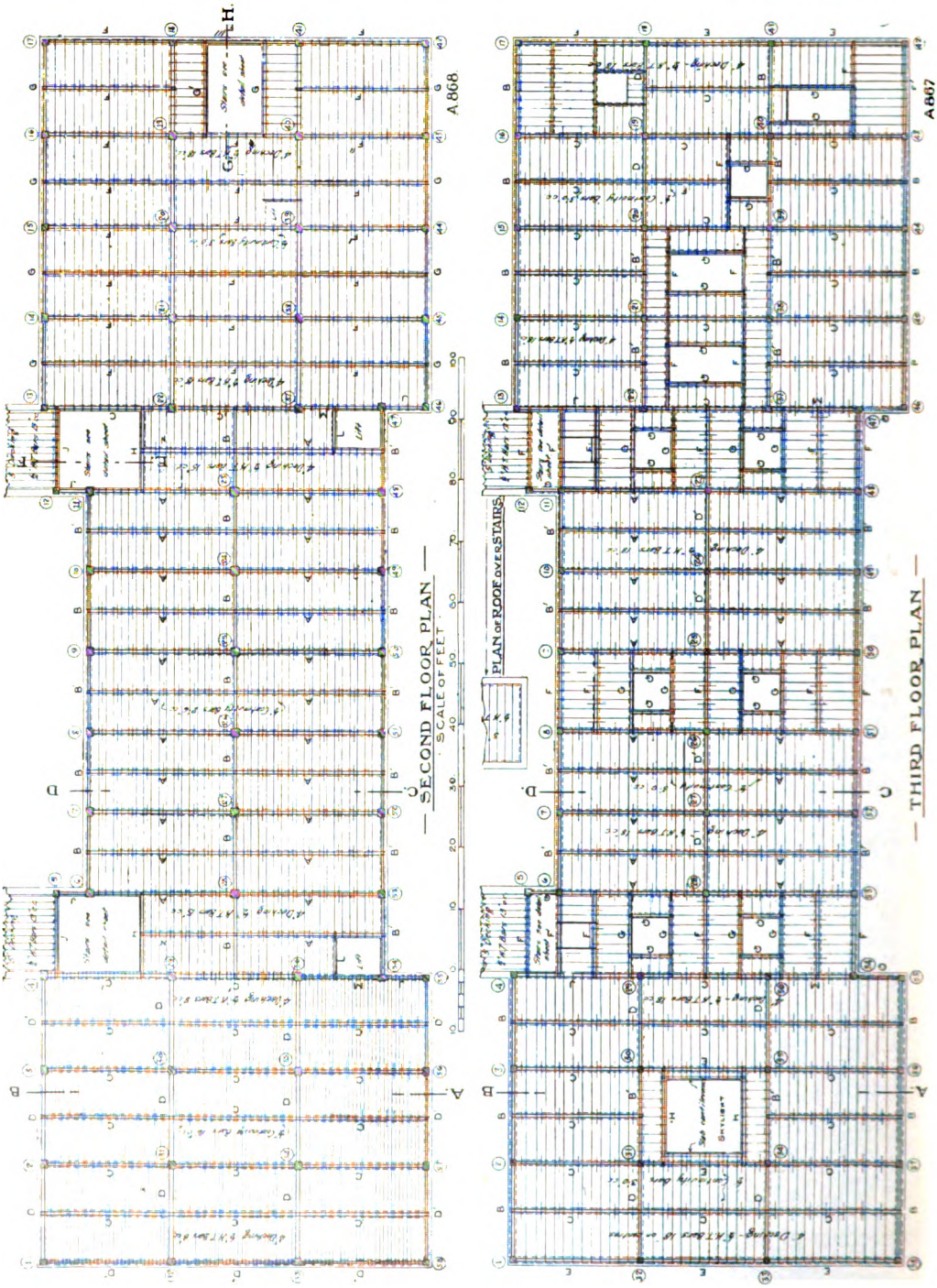

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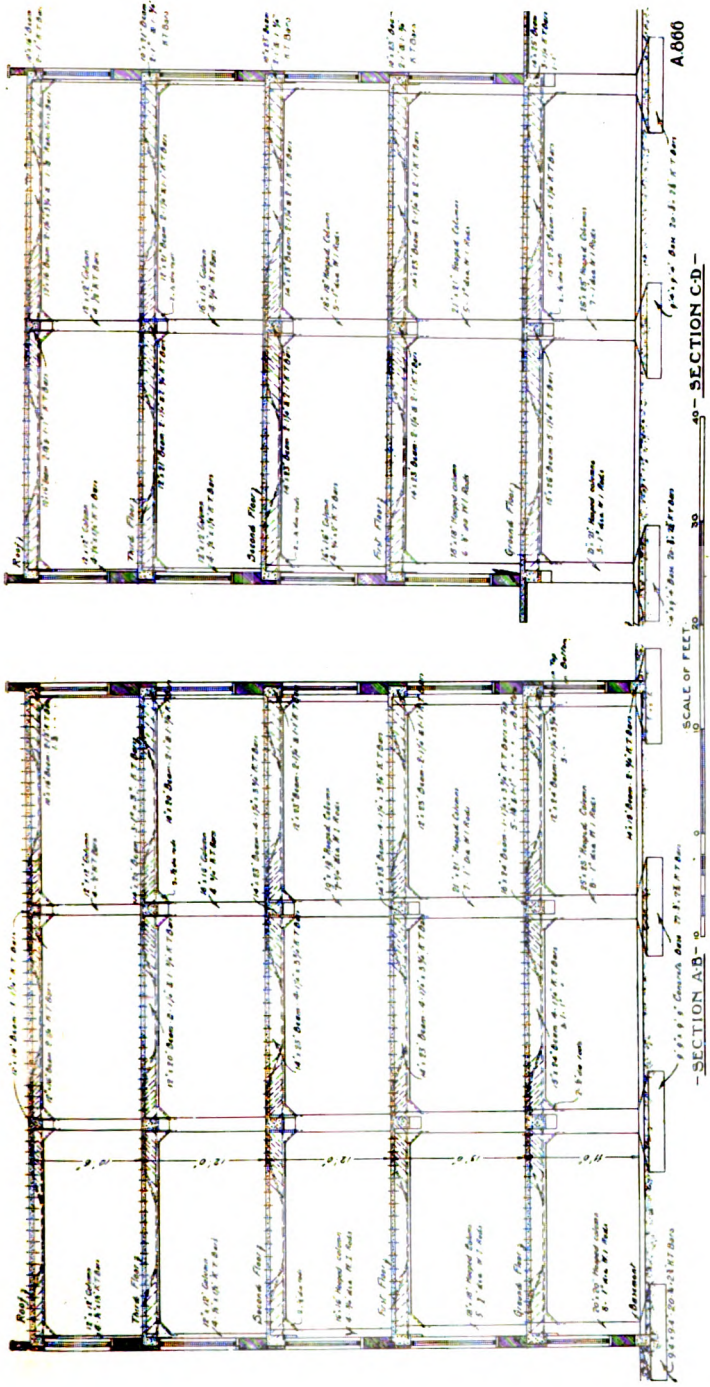

New Telegraph Stores, Birmingham.
Sections showing Kahn Bar reinforcement.

for a superimposed load of 336 lbs. per ft. super, whilst the first and second floors are to carry 224 lbs. per ft. super, and the third floor 168 lbs. per ft. super.

The entire skeleton of building, including columns, beams, decking, etc., was erected in reinforced concrete, with floors and roof of the same material, and the main beams have generally a clear span of 23 ft. to a total depth of 2 ft. There is a facing of brick and stone work carried at each floor level on reinforced concrete beams, as will be seen from an illustration on page 457. The walls have been practically erected in panels and carried entirely by framework, none of the walls carrying any of the floor loads.

As indicated before, the similarity between the first and second

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block is great, the chief difference being in the fact that the first block, of which we show the plans and sections, is intended to carry a somewhat heavier load.

There is little in the detail that calls for special attention, the plan of this structure being what may be termed a "straightforward" one, complications thereby being avoided.

There is no better example of the suitable application of reinforced concrete than in structures of simple plan, and it is in such buildings that the great economy of the new material can best be obtained.

On page 458 we show a testing operation on block "A," details of which are as follows :—

The area of the slab tested was 323 ft. 8 in. super. Clear span of beam supporting slab was 21 ft. 6 in. Unit load imposed on slab 7½ cwts. ft. super. Total load imposed 121 tons 7 cwts. 2 qrs. Total deflection of beam was 11/32 in., returning to normal position on removal of load.

NEW TELEGRAPH STORES, BIRMINGHAM.
Top floor of Block "A."

The following are particulars of two tests on block "B" :—

Report of Test on Ground Floor, Block "B."

Normal load 3 cwts. per ft. super.
Full load 4½ cwts. per ft. super.
Area tested 324 ft.
Thickness of slab 4½ in.
Clear span of beams 23 ft.

October 31st, 1908, 7 a.m., deflection indicator set, loading commenced. 5 p.m. same day load of 24 tons 6 cwts. (1½ cwts. per ft. super.) on, deflection 2/64th-in. Load left on until November 2nd, 6 a.m., then doubled—3 cwts. per ft., or total load of 48 tons 12 cwts. This load was on by 11.30 a.m., deflection 5/64th in. Double load remained on until 12.30 p.m., then further 1½ cwts. per foot (24 tons 6 cwts.)

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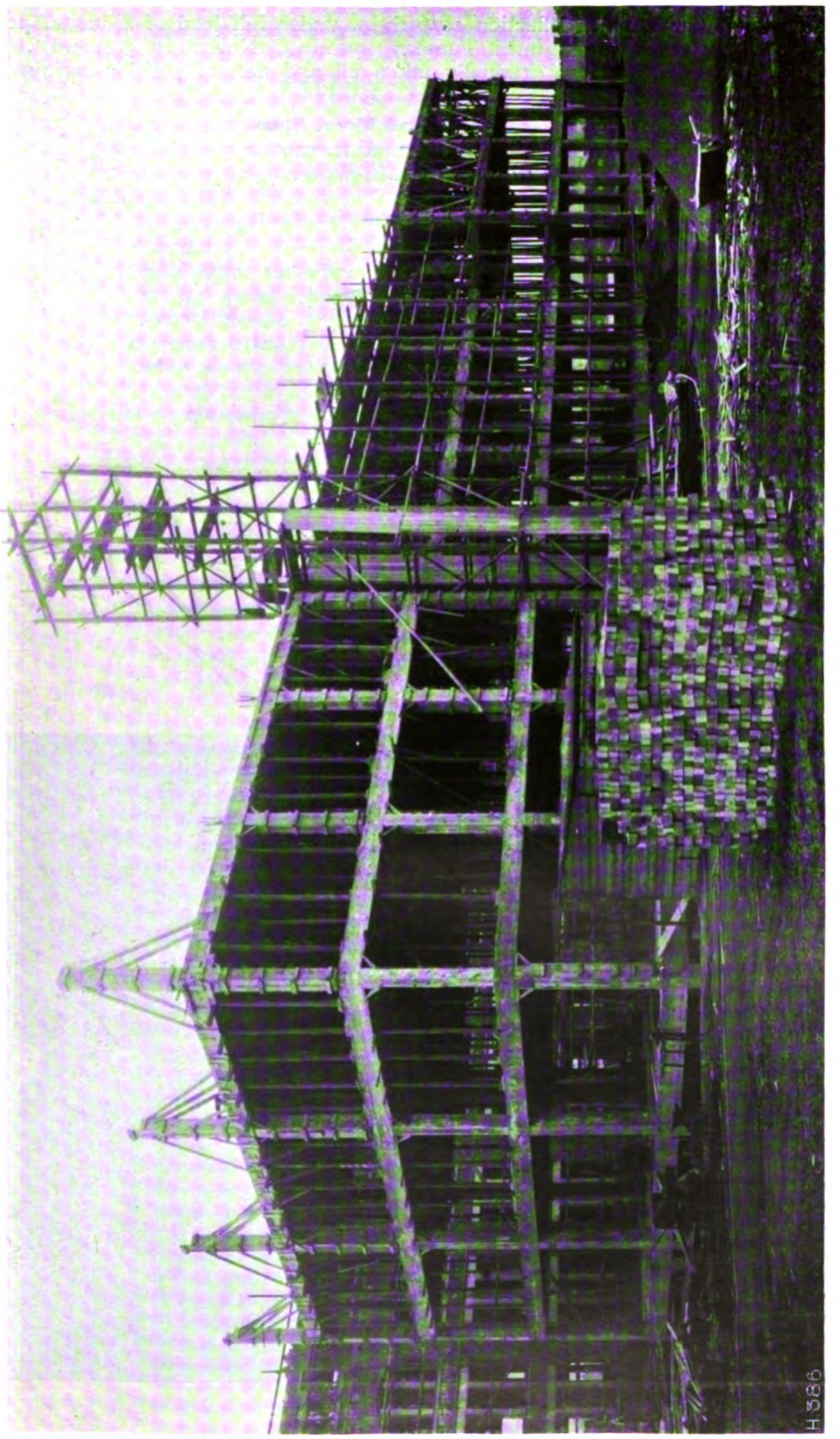

New Telegraph Stores, Birmingham
Block "B" in course of construction.

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added and on by 2.30 p.m., deflection 10/64th-in. under full load of $4\frac{1}{2}$ cwts. per ft. super. This load remained until Tuesday morning, November 3rd, no further deflection taking place. Load gradually taken off and normal position regained by 5 o'clock.

Report of Test on Second Floor, Block "B."

Normal load 2 cwts. per ft. super.
Full load 3 cwts. per ft. super.
Area tested 324 ft.
Thickness of slab $4\frac{1}{2}$ in.
Clear span of beams 23 ft.

November 2nd, 1908, 7 a.m., deflection indicator set, loading commenced. 11.15 a.m. same day, normal load on, deflection under beam 13/128th-in. Load left until 12.30 p.m. same day and additional 1 cwt. per ft. added, 3 cwts. on by 2.30 p.m. same day, deflection 13/64th-in. 2.40 p.m. same day, load removed, floor immediately commenced to regain normal position—reached by 4 p.m., there still being load of 2 tons on floor.

Both floors examined afterwards, no signs of any cracks, etc., whatever.

New Telegraph Stores, Birmingham.
Test on Block "A

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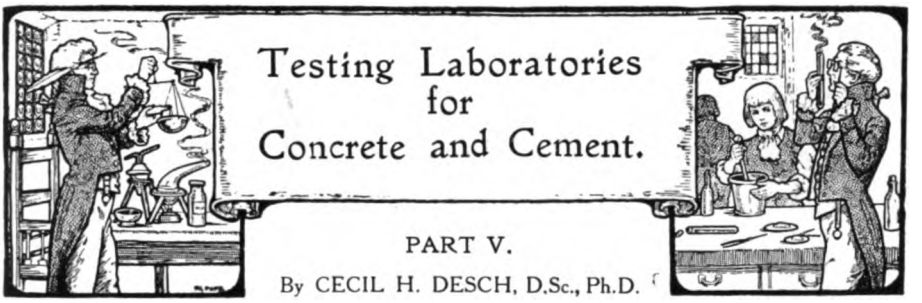

Testing Laboratories for Concrete and Cement.

PART V.

By CECIL H. DESCH, D.Sc., Ph.D.

The absence of an official laboratory devoted to investigations with concrete and cement may be said to account in no small degree for the dearth of reliable data as to reinforced concrete as designed and executed in this country.

Some testing station enjoying official support, or if conducted by some independent technical body at least enjoying official recognition, would be very much in place at the moment, and it might be a matter worthy of the attention of the Concrete Institute to consider the possibility, and ways and means of obtaining for the British Empire some laboratory of this description.

We have presented particulars of a number of laboratories in the preceding articles, and this article deals with one conducted as a private industrial enterprise, but enjoying the reputation of absolute reliability, and thus being frequently commissioned to undertake work for public departments.—ED.

It has been pointed out in previous articles of this series that testing laboratories in this country, unlike those on the Continent, have been almost entirely the outcome of private enterprise, unsupported by State or other official subsidies. This being the case commercial considerations have naturally taken the first place in the conduct of most laboratories, the investigations carried out being as a rule directed to some immediate practical object. Great masses of experimental data are accumulated in the course of such routine work, but those engaged in commercial testing rarely have the time or the opportunity to follow up definite lines of investigation as the staff of a subsidised laboratory is able to do. To undertake such researches in a private or commercial laboratory involves a considerable sacrifice of time and money on the part of the investigator. There is therefore a special interest in observing the original work which has been done under such conditions.

The pioneer of the systematic testing of materials as a means of controlling constructional work was the late David Kirkaldy. His early experience in marine engineering convinced him of the value of systematic tests in controlling the working of machines, and it was natural to apply the experience thus gained to the subject of materials of construction. His work on the subject of iron and steel testing, published in 1862, contained an account of a very thorough series of tests made in connection with shipbuilding. At this time the idea of making tensile and compressive tests of materials a condition of technical specifications was new to the engineering world, and it is strange to read in the technical literature of that time how slowly the necessity of such tests impressed itself on the public. Even after it had become the practice to specify that the iron and steel used in a structure should be tested the requirement was often met in the most perfunctory way, one or two small test-pieces being taken to represent a consignment of several thousand articles. The reports of such an enquiry as that into the Tay Bridge disaster are melancholy reading, and it is difficult to realise from our modern standpoint the indifference of so many engineers at the time towards precautions which we now regard as of vital importance.

It was in the course of his early experiments that David Kirkaldy became impressed with the necessity of making experiments on full-sized structural members. The only testing-machines then available for heavy work were the old horizontal machines for

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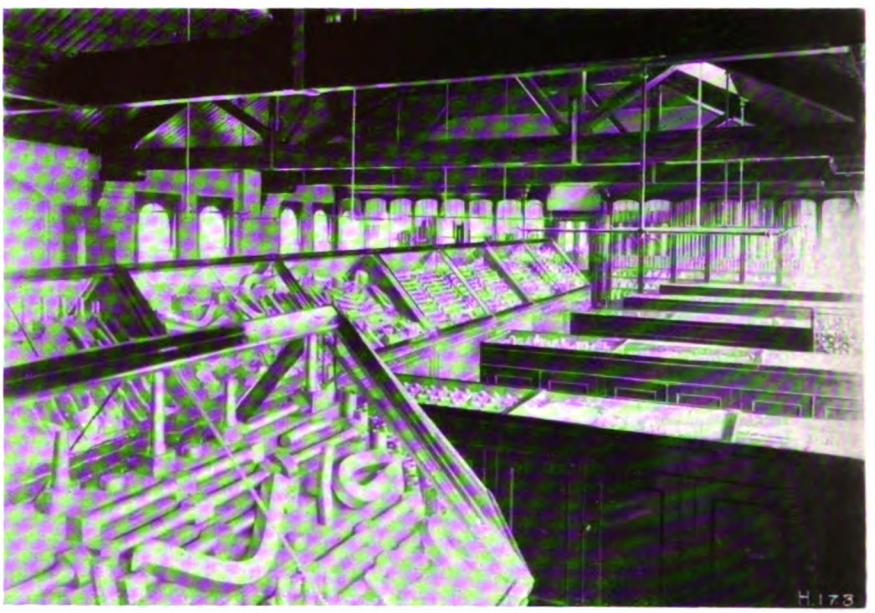
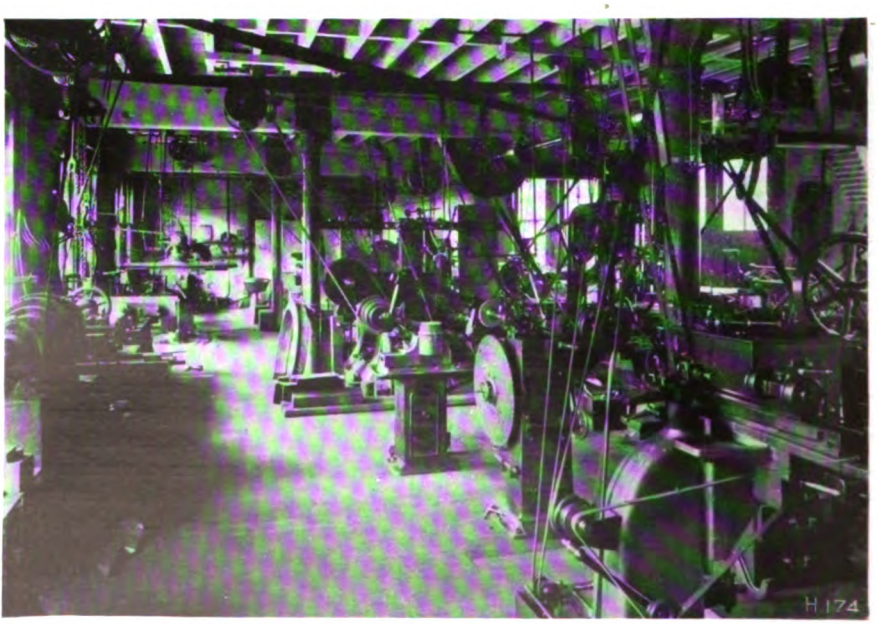
testing chain cables, which were not susceptible of any great accuracy. This led him to design his well-known horizontal testing machine, which has become the parent



THE PRINCIPAL MUSEUM.



THE MAIN MACHINERY ROOM.

FIGS. 1 & 2 Messrs. Kirkaldy's Testing Laboratory, London.

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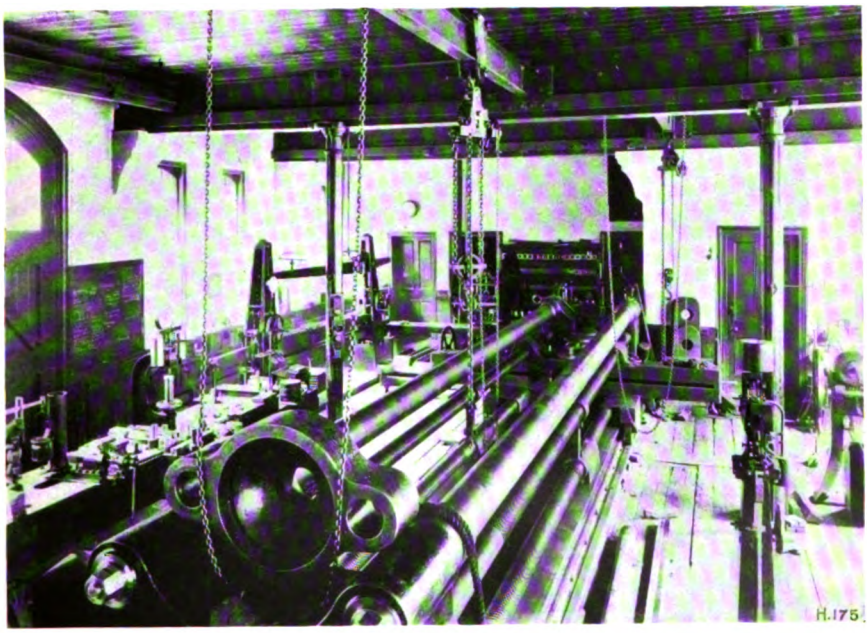
of almost all later types. In this machine the hydraulic ram acts directly on one end of the test-piece, whether in tension or compression, the other end being applied to a bell-crank lever, which is connected with a system of steelyard levers, by means of which a balancing load is applied. The position of the sliding weight on the steelyard gives the load acting on the specimen. The same machine may also be used, by re-arranging some of the parts, for torsional, transverse bending, and shearing tests. The machine, capable of applying a load of 450 tons, was erected in Southwark in 1866, and removed to its present position in 1874.

The present testing works of Messrs. Kirkaldy and Son occupy a large building of four floors and basement in Southwark Street. The ground floor is occupied by the large testing machine and by the numerous smaller testing machines for special purposes; the first floor contains an equipment of machine tools for the production of test-pieces, etc., and the two upper floors are devoted to the museum described below.



THE LARGE TESTING MACHINE.
FIG. 3. Messrs. Kirkaldy's Testing Laboratory, London.

In the basement are the cement and concrete departments, and various miscellaneous appliances. The system of testing cement does not call for special description, as it is in accordance with the usual modern practice. It may be noted that briquettes are always mixed by hand, a trial mixing of two briquettes being made first to determine the consistence. This is also the practice in Zürich, and would appear to give the most satisfactory results. Unlike the Zürich practice, however, the moulds are filled by hand without mechanical ramming. Cubes of 3 in. side are used for the compressive tests. Concrete blocks are also made for compression, whilst numerous tests are also made on full-sized concrete and reinforced concrete beams and columns, as described later. Some early tests of concrete were made in connection with the Vyrnwy dam of the Liverpool Corporation.

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The museum of specimens at Messrs. Kirkaldy's works is unique, and is less well known than it deserves to be. Here may be seen almost every type of fracture and deformation which may be met with in the testing of materials. During the long experience of the founder of the firm and of his son an enormous number of tests have been made on materials naturally showing every degree of resistance to stress. Since the method of testing each material has been uniform throughout the history of the firm, and great care has always been taken to ensure the uniform application of the stress, the results are directly comparable with one another, and it is possible to study,

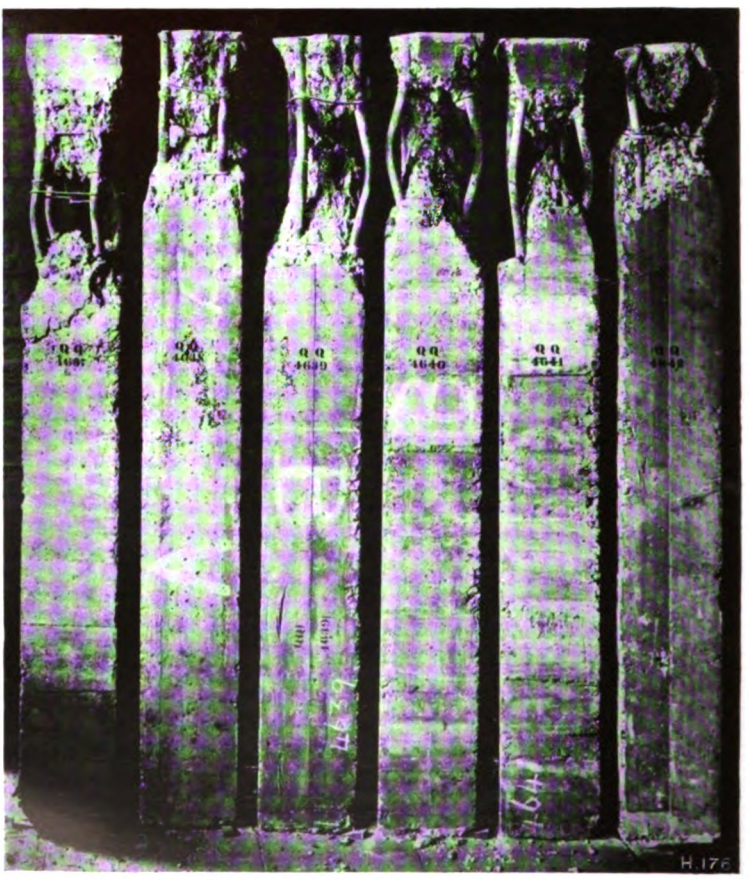

FIG. 4. VIEW SHOWING FRACTURES OF REINFORCED CONCRETE COLUMNS.
(Tested for the new General Post Office.)

with a degree of certainty unattainable where tests have been made by many different observers, the influence of the character of the material on the mode of deformation and fracture, when the conditions of testing are kept constant. Here is a rich store of accumulated data bearing on the question, still so obscure and imperfectly investigated, in spite of its practical importance, of the mode of yielding of bodies stressed beyond their limit of elasticity. The behaviour of brittle masses, such as concrete or building stone, is particularly interesting, and the influence of any lack of homo-

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geneity is most clearly seen when studying the direction of the planes or surfaces of fracture. This museum, the contents of which are clearly arranged and displayed, is readily shown to engineers and others interested in strength of materials.

To turn to the department with which CONCRETE is more immediately concerned, the chief interest lies in tests made with large reinforced concrete members, mainly compressive tests with columns and transverse tests with beams. In connection with the latter it is of interest to note that David Kirkaldy, some thirty years ago, constructed a machine for testing beams under distributed load, practically identical in design with that devised in recent years, quite independently, by Prof. Schüle of

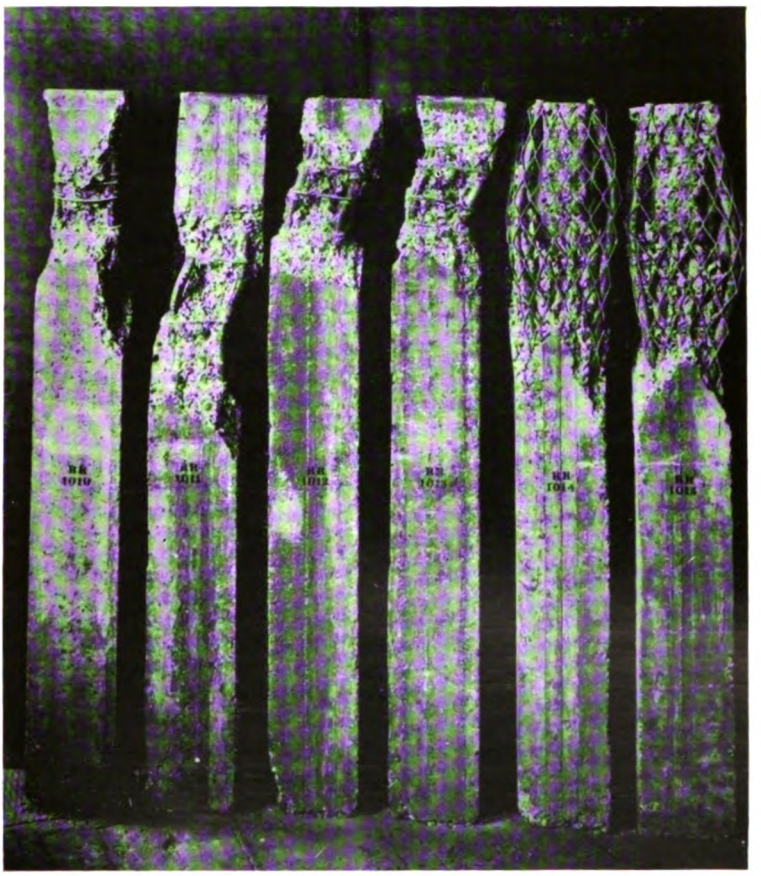

FIG. 5. VIEW SHOWING FRACTURES OF REINFORCED CONCRETE COLUMNS.
(Tested for the new General Post Office.)

Zürich, of which Messrs. Amsler-Laffon have now supplied a number to various testing laboratories. The machine was, however, in advance of its time, and engineers and contractors had not realised the importance of such tests sufficiently to be willing to spend the sums involved in testing large beams to destruction, and the machine, after one or two tests, has remained idle.

RECENT TESTS WITH REINFORCED CONCRETE COLUMNS.

Among the most interesting recent tests carried out by Messrs. Kirkaldy and Son with their large machine are some undertaken for H.M. Office of Works in connection

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with the new General Post Office, and by the courtesy of Sir Henry Tanner, I.S.O., we are enabled to give some particulars and photographs of these.

Twelve reinforced concrete columns, 9 in. sq. and 6 ft. long, were tested under thrust. The concrete used was composed of 1 yd. screened Thames ballast crushed to pass ¾-in. mesh, ½ yd. Thames sand, and 6 cwt. Portland cement, all machine mixed fairly dry. The age of the columns was from two and a half to three months. The reinforcement consisted of four 1 in. steel bars spaced 5 in. centres, and tied by $\frac{3}{16}$ in. wire links at intervals varying in the different specimens, except in two columns, the tying of which was accomplished by the use of expanded metal of 1½ in. mesh and ¼ in. × ⅛ in. strand, the slits running longitudinally. Two exactly similar columns of each type were tested, in order to secure trustworthy results. The ends of the columns were trued up before testing, and the depression was measured after each increment of load of 20,000 lb. The course of these depressions was remarkably uniform up to the point at which visible cracking took place.

Failure occurred in all the columns in the same way, namely, by crushing at a point from 1 to 2 ft. from the upper end, the concrete cracking away and exposing the reinforcement. The ultimate load varied from 85·2 to 107·5 tons, according to the distance apart of the binding ties, the highest results being obtained when the wires were 6½ in. apart throughout the greater part of the length, and 3 in. apart near the ends. The two columns with expanded metal binding failed at 73·1 and 76 tons, owing to spreading of the mesh.

The results emphasise the importance of sufficient tying of columns with wire. The application of a direct thrust to a column gives rise to a considerable bursting stress, which must be resisted by closely spaced transverse wires. *Figs.* 4 and 5 of our illustrations are very instructive from this point of view.

In addition to the columns four T-beams 10 ft. in span, and composed of the same concrete as the columns, were tested under bending stress. Two were reinforced as shown in the sketch; in the remaining two expanded metal 1½ in. mesh, ⅛ in. × ¼ in. strands, placed with the long way of the mesh vertical, was used instead of the hoop iron stirrups. The beams broke under loads of 7·13, 7·02, 6·76, and 7·27 tons respectively, cracks appearing in all cases first at the under side, and extending to the lower edge of the decking (*see Fig.* 6).

The utility of such tests with full-sized structural members is obvious, as only in this way can a comparison be made between different modes of placing the reinforcement. As we have seen in dealing with Continental laboratories, it is from tests of this kind, performed with the aid of heavy testing machines, that the most valuable information has been obtained.

The author is indebted to Mr. W. G. Kirkaldy for the facilities afforded him in visiting the laboratory, and for the illustrations accompanying this article.

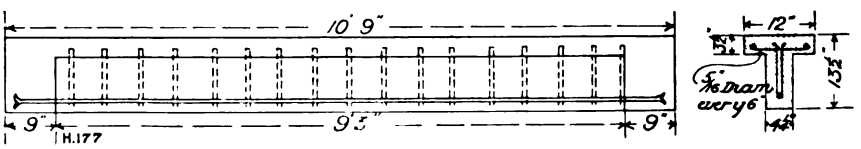

FIG. 6. TEST PIECE. REINFORCED CONCRETE BEAM.
Tested for the New General Post Office.)

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FIG. 1.

CONCRETE TUBES AS SEWER PIPES.

By
E. R. MATTHEWS,
A.M.Inst.C.E., F.R.San.I.
(Borough Engineer of Bridlington).

So much interest has been taken in the utilisation of concrete tubes as sewer pipes that we have had prepared for us by ***Mr. E. R. Matthews, A.M.Inst.C.E.,*** *the Borough Engineer of Bridlington, the following article, which deals with the matter from every aspect.—ED.*

Introduction.—The use of cement concrete in the construction of sewer pipes has now grown to such an extent as to warrant the most careful enquiry as to the suitability of this material for the purpose named, and as to the advantages and disadvantages of using concrete pipes compared with other materials, such as iron, brick, or glazed fireclay.

It is the author's intention to first deal with the advantages of using concrete tubes for the purpose referred to, then to consider the action of acids on cement, the durability of cement exposed to running water, the velocity of flow in glazed fireclay pipes versus cement pipes, and the permeability of the former compared with the latter. In addition, certain tests made for the purpose of discovering the loss of cement in solution will be dealt with, and the methods and cost of manufacture of concrete tubes in Great Britain and the United States will be described.

FIG. 2. JOHN ELLIS & SONS' CONCRETE TUBES (EGG-SHAPED).

CONCRETE TUBES AS SEWER PIPES.

For many years past cement or concrete sewer pipes have been used in America; these have varied in diameter

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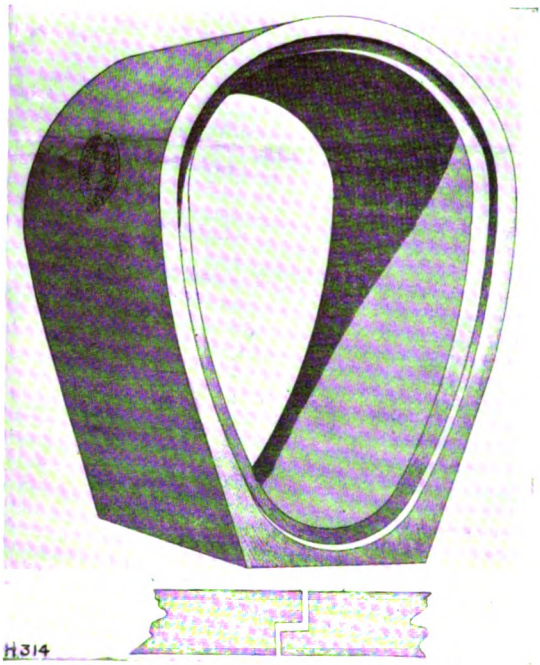

FIG. 3. CONCRETE TUBES (EGG-SHAPED).

from 12 in. to such a size that the pipes became so large that it was more economical to form the sewer in place than to make pipes outside and transport them to the trench (*Figs* 1 and 7).

Advantages of using Cement Pipes.—(*a*) *Economy over brick sewers and large glazed pipe sewers.*—A sewer formed of concrete tubes, circular or egg-shaped, can be constructed cheaper than if of brick. In the United States the cost is less than that of vitrified pipes, but in this country for sewers up to 18 in. dia. the cost of the concrete tubes exceeds glazed fireclay pipes; above this diameter, however, the cement tubes are more economical.

(*b*) *Greater strength than brick sewers or ordinary sewer pipes.*—Concrete pipes if properly made should be designed to resist not only a bursting pressure due to a complete filling of the sewer, and a head equal to that which would exist if the man-holes were full and the storm water were flowing out of the street grates, but also compression; this being so it is possible to construct a sewer of this kind nearer to the surface than would be advisable in the case of vitrified pipes. Concrete pipes are also tougher and less brittle than ordinary sewer pipes, so that they are less easily broken by handling. The strength of cement tubes, if well made, is also superior to that of brick sewers. *Figs* 3 and 4 represent concrete tubes (circular and egg-shaped) which in the author's opinion are very much stronger than an ordinary brick sewer, and being free from longitudinal joints they are certainly more water-tight.

(*c*) *Increase in strength with age.*—A concrete pipe sewer requires no maintenance, and increases in strength with age, which is a great advantage over the ordinary forms of sewers. Concrete sewers are in use almost exclusively in Paris and Vienna, and these illustrate the fact that after many years' use the sewers are stronger and in better condition than when first constructed.

(*d*) *Different shapes of concrete sewers.*—It is customary in America to construct concrete sewers with a flat, broad base; by so doing the sewer rests securely upon a flat foundation, as compared with the circular bed required for circular pipes. It is needless to demonstrate the advantages of the former method.

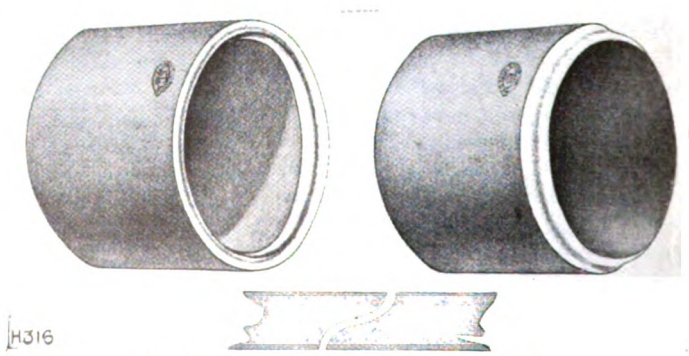

FIG. 4. CIRCULAR TUBES (JOHN ELLIS & SONS).

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It has also been found impracticable to give vitrified pipes a true oval or "egg" shaped section owing to the warping in burning, whereas in concrete sewers any desired section may be easily obtained.

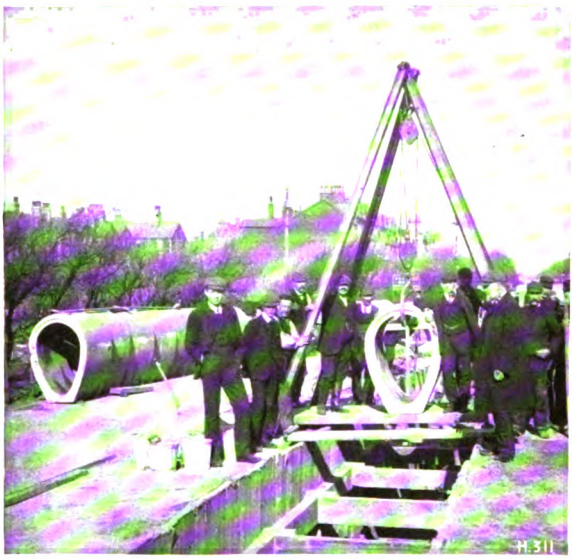
Concrete tubes may be made absolutely true in sectional shape, which fact cannot be stated regarding vitrified pipes. It is possible to give the former, in consequence of their uniform shape, slanting or splayed butt joints; in vitrified pipes such joints are not possible, a certain amount of play being necessary between the spigot and socket to allow for irregularities that may have occurred in burning.

Action of Acids on Cement.—Some have objected to the use of concrete pipes for sewers on the grounds that the acids (such as sulphuric acid) which are likely to occur in such sewers will attack the cement and that the latter will very soon become eroded. They contend that vitrified pipes withstand the detrimental effects of such acids.

The author's experience has taught him that when the cement is thoroughly hardened, acids, carbonic and sulphuric, have practically no injurious effect upon the cement.

His opinion in this matter is supported by M. Tedesco,* a well-known authority on the subject, and by German authorities, such as Shoch, Schuman, and others.

Reverting again to the question of acids, surely sewage contains no more acid than water used in the manufacture of paper, yet we find concrete is used very largely in the construction of paper mills. All the floors of the Long Island Paper Mill, Long Island City, U.S.A., are of cement concrete. The



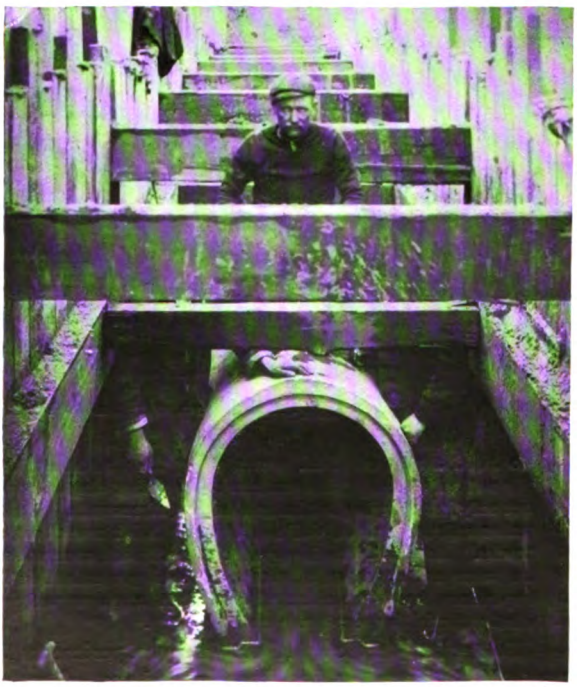


FIG. 5. BASALT CONCRETE TUBES LAID AT ST. ANNE'S-ON-SEA

* *Beton and Reinforced Concrete*, by M. Tedesco.

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author would also refer to the digestors in the paper mills at Holyoke, Mass, U.S.A.; these are lined with concrete.

In sewage there is seldom, if ever, a concentration of acids such as to be injurious to the cement; the acids usually are well-diluted, so that if concrete will withstand acids—hydrochloric and sulphuric, as used to destroy the wood pulp in a paper mill—little fear need be entertained as to their effect on the concrete in sewer pipes.

Durability of Cement Exposed to Running Water.—The excellent state of preservation of the many concrete sewers and aqueducts in the United States and in many European cities, some of which have been in use for a number of years, is a good proof of the ability of concrete to resist running water. Among those that might be referred to are sewers of this class in Paris, Vienna, New York, Chicago, Harrisburgh, Williamsport, and many other cities.

The City Engineer of Jackson, Mich., U.S.A., writes concerning the concrete sewers in that city as follows:—

"The City of Jackson commenced several years ago to experiment with different kinds of sewers, and at the present time we have some three miles of concrete sewers ranging from 15 in. to 66 in. dia. These sewers have given such universal satisfaction that we are now beginning

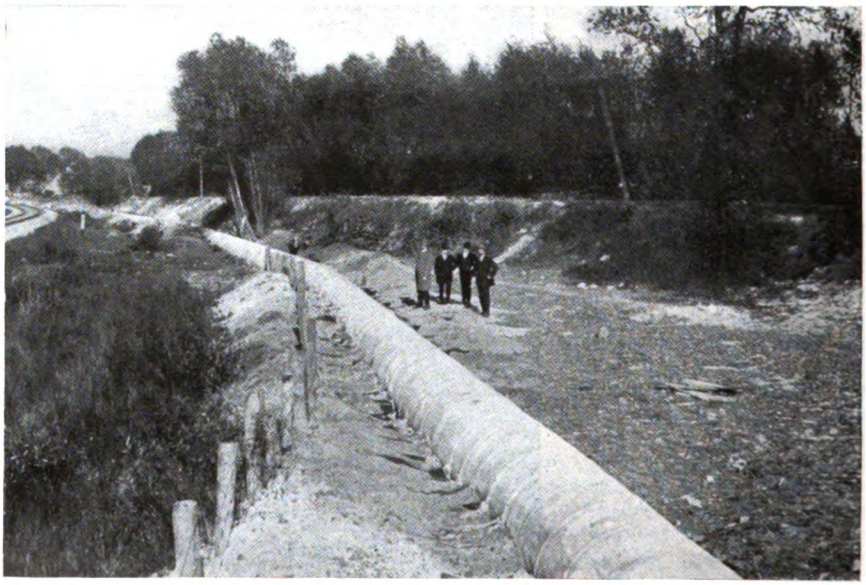

FIG. 6. CONCRETE PIPES IN MISHAWAKA, IND.

to build a mile of 48-in. sewer, using the Reinforced Concrete Pipe Company's concrete pipe We not only consider this superior to any other class of sewers, but there is a saving in the expense, not only in the laying but in maintaining afterwards. We are permitted to use this pipe in building under railroad tracks, while in building brick sewers we are obliged to use iron pipe under the tracks. Anybody who is opposed to reinforced concrete sewer construction is either ignorant of its value under proper construction or is prejudiced in favour of some other material, for our experience has demonstrated fully that when properly used Portland cement concrete is the ideal material for sewer construction."

The author has carried out many experiments in order to ascertain the relative strength of concrete when kept in and out of water respectively, and when placed alternately in and out, and his tests have proved beyond doubt that concrete is much stronger when kept continuously in water than when kept in air; when placed alternately in and out of water, although not so strong as if kept in water, it is decidedly stronger

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than when kept in air. No fears, therefore, need be entertained as to any detrimental effect of running water on concrete.

Velocity of Flow in Glazed Fireclay Pipes versus Cement Pipes.—While the author is bound to admit that the glazing of vitrified pipes gives the sewage passing through such pipes a slightly greater velocity, yet this advantage is practically cancelled in practice by the obstructions to the flow caused by the imperfect joints in ordinary sewer pipes compared with the close joints in concrete tubes.

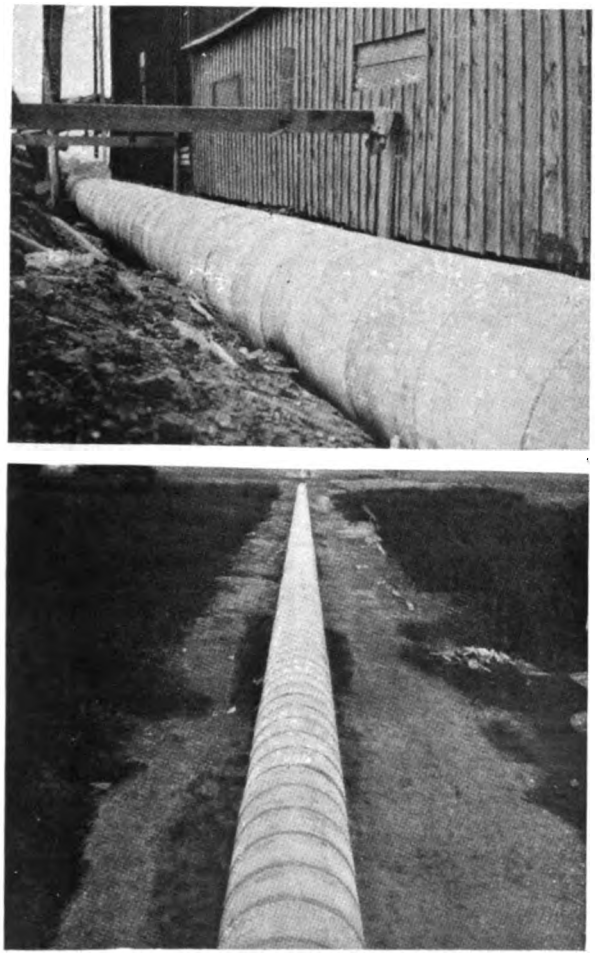

FIG. 7. CONCRETE PIPE IN WAUKEGON, ILL.

Tests for Loss of Cement in Solution.—Various tests have been made from time to time to ascertain the loss in weight of cement pipes through the solution of the cement by its coming in contact with running water. The most interesting tests which the author has met with are those carried out in December last by Mr. A. O. Anderson, of Lake City, Iowa; these experiments were described fully by Mr. A. O. Anderson in *Engineering Contracting*. They might be briefly described as follows :—

Specimens of various cement tubes and of various ages were selected. These were thoroughly dried, then brushed with a stiff brush to remove all loose particles. After each specimen had been weighed it was placed in boiling water; the duration of the boiling varied with the different specimens. After being boiled the test pieces were dried and weighed, the results being as follows:—

Size of Pipe Test Piece was taken from	Age of Pipe	Proportions of Concrete	Original Dry Weight	Weight after Boiling 1 Hour	Weight after Boiling 7 Hours
16 in.	About 60 days	1 to 3½	75·450 g.	74·780 g.	75·260 g.
24 in.	About 2 years	1 to 4	53·520 g.	53·112 g.	53·305 g.

It will be observed that at the end of the first hour's test a slight decrease occurs, but upon further boiling the loss in weight is practically made good. Professor Marston† has given the increase in strength with age of cement pipes in Table A.

† *Cement Pipe and Tile* (Hanson).

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It is altogether probable (says Professor Marston) that in an extensive series of tests the strength would be found more nearly proportionate to the square of the thickness of the shell.

Professor Marston has given in the following table the tests to which he subjected cement pipes of various ages, and this information is very useful :—

TESTS OF STRENGTH OF 12 TO 20-IN. CEMENT DRAIN PIPES.

Proportion		Dimensions, ins.			Strength Load per lin. in		Remarks
Cement	Sand	Length	Depth	Thickness	2 Months	11 Months	
1	3	24	20	2¼	89	69	Cracked
1	3	24	20	2¼	73	—	—
1	3	24	20	1¾	68	142	—
1	3	24	20	1¾	70	175	1½ in. shell
1	3	24	18	2¼	115	215	2-in. shell
1	3	24	18	2¼	141	299	2-in. shell
1	3	24	18	1¾	109	221	1½-in. shell
1	3	24	18	1¾	79	81	Cracked
1	3	24	12	2	116	365	—
1	3	24	12	2	155	470	2¼-in. shell
1	3	24	12	1½	135	181	—
1	3	24	12	1⅞	99	218	—

METHODS AND COST OF MANUFACTURE, ALSO TESTS, IN THE UNITED STATES.

Methods of Manufacture.—In America the concrete pipe industry has grown to such an extent that we find in the market a score of machines, each guaranteed to be capable of manufacturing concrete pipes in the most efficient and economical manner possible. Amongst these are the Schenk cement pipe machine, manufactured by the Cement Tile Machinery Co., of Waterloo, Iowa. This machine consists of a pyramidal frame about 8 ft. in height, a revolving table and shaft, a boot, from which the moulds are filled, and a bucket elevator for raising the concrete to the boot.

(*Table A.*)

PER CENT. OF INCREASE IN STRENGTH OF CEMENT PIPES BETWEEN THE AGE OF TWO AND ELEVEN MONTHS.

Diameter	Per Cent. Increase
20 in. (thin)	130
18 in. (thick)	140
18 in. (thin)	136
12 in. (thick)	205
12 in. (thin)	71

The Crescent sewer pipe machine, made by the Raber and Lang Manufacturing Co., is of simple construction, and consists of an iron pallet, an outer hinged shell, a collapsible core and cap for same, and a tamper. The outer casing and the core are of heavy sheet steel.

Other machines in use are the Ferguson patent cement drain tile machine; the Wolverine drain tile mould; the Miracle power tile machine; Thomas's glazed sewer pipe machine; the Reinforced Concrete Pipe Co.'s machine; the Besser machine; Hudson moulds, Miracle hand moulds, and Easy hand moulds for large sizes, made by the Waterloo Cement Machinery Co. Each manufacturer has his own stock thicknesses of pipes, and these vary, as the following table shows :—

THICKNESS OF SHELL ADOPTED BY DIFFERENT MANUFACTURERS OF CONCRETE PIPES.

Diameter, ins.	4	5	6	7	8	9	10	12	14	15	16	18	20	22	24	26	27	30	33	36	39	40	42	48	54	60	66	72
Reinforced Concrete Pipe Co.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2½	—	3	3½	3¾	4	4½	—	4½	5	5½	6	6½	7
Hudson Manufacturing Co.	¾	⅞	⅞	—	1	1	1¼	1⅜	1½	1½	1⅝	1⅞	1¾	2	2	2	—	2½	—	3	—	—	—	—	—	—	—	—
Raber & Lang ..	¾	¾	¾	⅞	1⅛	1⅛	1¼	1⅜	1⅛	1⅛	1¼	1⅜	1¾	—	2	—	—	2½	—	3	—	—	—	—	—	—	—	—
Ferguson Power Machine	⅝	9/16	½	11/16	¾	—	⅞	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Schenck Power Machine	⅝	9/16	½	11/16	¾	—	⅞	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Easy Moulds ..	—	—	—	—	—	—	—	1⅛	1⅜	—	1⅛	1⅜	1¾	1⅞	2	—	—	2½	—	3	—	3½	—	—	—	—	—	—
Miracle Moulds ..	¾	1	1	—	1	1⅛	1⅛	1⅛	—	1⅛	1⅜	1¾	1¾	—	2	2	—	2½	—	3	—	—	—	—	—	—	—	—
Miracle Power Machine	⅝	¾	⅞	⅞	11/16	—	¾	⅞	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electric Power Machine	⅝	⅞	¾	¾	¾	—	⅞	1	1⅛	1⅛	1⅛	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electric Hand Moulds	—	—	—	—	—	—	—	—	—	—	—	1¾	2	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Besser Power Machine	½	9/16	⅝	¾	⅞	—	1	1	1⅛	—	1⅛	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Besser Hand Moulds	—	—	1¼	—	1⅛	—	1¾	2	—	2	—	2	2½	—	2½	—	—	2½	—	3	—	—	—	—	—	—	—	—

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Cost.—This varies in each case, but as an average guide the following table gives a comparison between the cost of cast-iron pipes and concrete pipes as used by Mr. O. P.

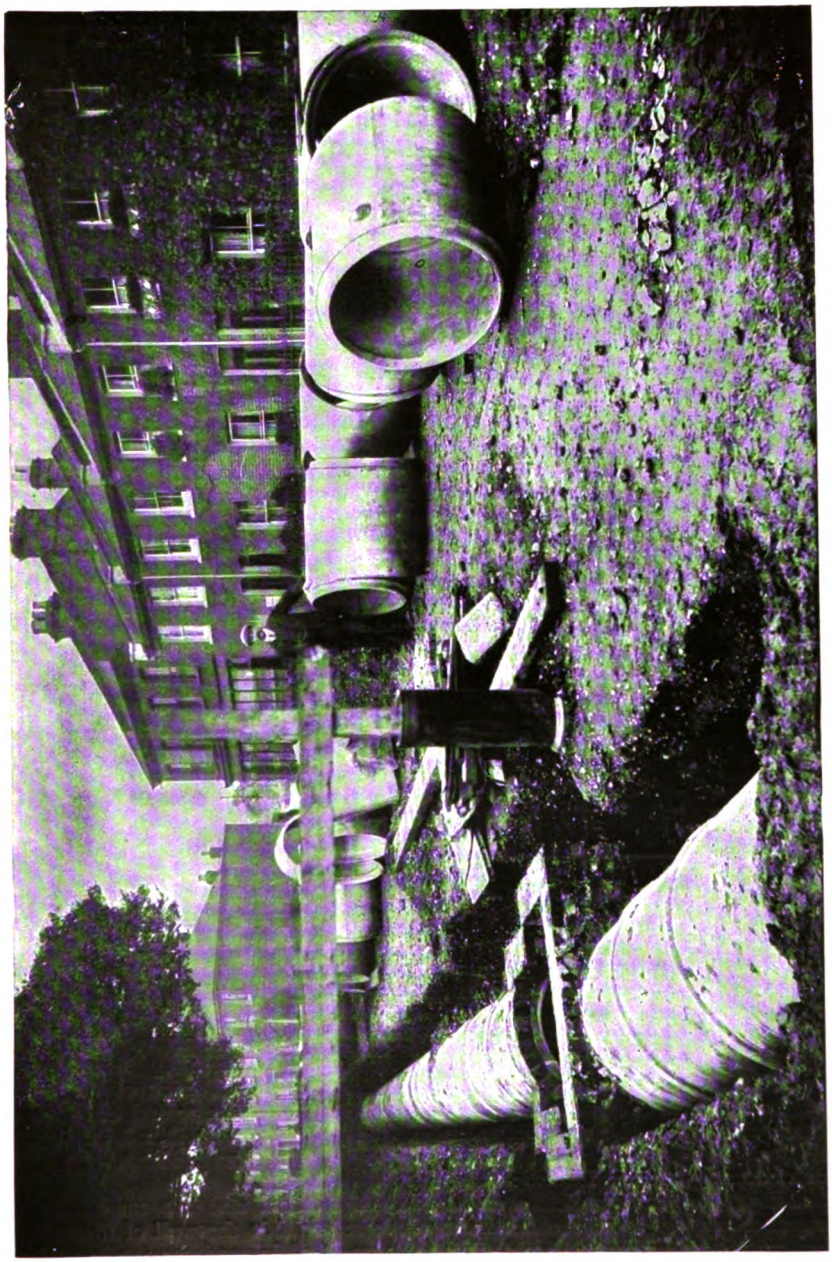

FIG. 8. JOHN ELLIS & SONS' CONCRETE TUBES.

Chamberlain on the Chicago and Illinois Western Railroad, and described by him in a paper read before the Western Society of Engineers, U.S.A. :—

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TABLE SHOWING RELATIVE THICKNESSES, WEIGHTS, AND COST OF "STANDARD" CAST-IRON PIPE AND CONCRETE PIPE.

Size and Kind of Pipe	Thickness in Inches	Weight, lbs. per lin. ft.	Cost per lin. ft.
			Dollars
12 in. dia., cast iron	$0\frac{33}{64}$	75	2.44
12 ,, concrete	2	88	0.16
18 ,, cast iron	$0\frac{37}{64}$	167	5.43
18 ,, concrete	3	220	0.36
24 ,, cast iron	1	250	8.13
24 ,, concrete	$4\frac{1}{4}$	420	0.68
30 ,, cast iron	$1\frac{1}{16}$	334	10.86
30 ,, concrete	$4\frac{1}{2}$	602	0.88
36 ,, cast iron	$1\frac{1}{4}$	450	14.63
36 ,, concrete	$4\frac{3}{4}$	676	1.10
42 ,, cast iron	$1\frac{3}{8}$	600	19.50
42 ,, concrete	$5\frac{3}{4}$	960	1.55
48 ,, cast iron	$1\frac{7}{16}$	725	23.56
48 ,, concrete	6	1,131	1.83

The concrete used in making these pipes was composed of 1 part American Portland cement to $3\frac{1}{2}$ parts of limestone screenings and crushed stone, these being capable of passing through a $\frac{3}{4}$-in. screen after everything that would pass through a $\frac{1}{2}$-in. screen had been removed. The figures given in the foregoing table are based on the assumption that a cubic yard of concrete costs 7 dols., and that cast-iron pipes cost $3\frac{1}{4}$ cts. per lb.; these prices being about the average cost in the States.

Tests.—Space will not permit of a description in detail of the number of tests to which concrete pipes have been subjected in America (see first table on page 470). The author also presents the following table, which is a tabulated account given by Mr. Homer A. Reid of certain tests which were carried out in Brooklyn recently.

Size and Description	Thickness	Breaking Weight
12 in., round, flat base	$1\frac{1}{16}$	10, 624 lbs.
18 in., egg, ,, ,,	$1\frac{5}{8}$	18,785 ,,
18 in., egg, ,, ,,	$1\frac{5}{8}$	12,287 ,,
18 in., egg, ,, ,,	$1\frac{5}{8}$	13,190 ,,
24 in., egg, ,, ,,	2	26,547 ,,

TYPICAL EXAMPLES OF CONCRETE PIPE SEWERS.

In the United States.—In the city of Mishawaka, Ind., during the year 1908, about 6 miles of concrete sewers were laid; these were 42 in. dia., and were reinforced. The pipes were in 3-ft. lengths (see *Fig.* 6), each being reinforced by five longitudinal bars and two transverse circular bands. At each joint a tie band was attached, which fitted into a groove in the pipes. The pipes were manufactured by the Reinforced Concrete Pipe Company.

In Great Britain.—During the past three of four years a good many concrete pipe sewers have been laid in this country, some reinforced, others not. For the most part these sewers have been circular in section, but some important egg-shaped ones have also been put in. The author will first describe one or two of the latter.

Fig. 5 shows concrete egg-shaped sewers recently put in by Messrs. Johnson Bros. for the St. Anne's-on-Sea Urban Council, under the direction of Mr. Gregson, their engineer. The tubes manufactured by this firm are circular and egg-shaped, the former varying in size from 12 in. to 40 in., the latter from 12 in. × 8 in. to 60 in. × 40 in. Each tube is made with a flat seating to give it a firm bedding. The methods of manufacturing are as follows:—

The pipes are cast vertically in sheet steel moulds, and are rammed by hand with rammers varying with the thickness of the material in the wall of the tube. The mixture consists of graduated basalt chippings up to $1\frac{1}{4}$ in. and sand, all of which are thoroughly washed, and Portland cement of a medium setting quality. The moulds are removed immediately the tube is made, the concrete being of such consistency (*i.e.*, it is not made wet but is kept as dry as possible) that the tubes will stand without

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assistance and without warping. In from four to seven days the tube is taken out of the moulding house and stacked on its bottom, when it is well watered every day for three months, and then only occasionally until six months, when the tube is ready for

FIG. 9. JOHN ELLIS & SONS' CONCRETE TUBES.

delivery. The pipes are not reinforced unless specially requested, as it is found they are sufficiently strong without it. The joint of these tubes is ordinary Spickett and Fossett square cut. They are all made in metre lengths, except the very large sizes,

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which are made in half that length, and are tested to take 5 tons along the whole length on a knife edge.

Messrs. John Ellis and Sons, of Leicester, are also makers of concrete tubes (steel ribbed), and have laid or supplied pipes for many sewers of this type.

The material used in the manufacture of tubes by this firm consists of Portland cement and Mountsorrel granite in the proportions of 3 to 1. The granite is crushed, washed, and passed through a ¼-in. mesh. The tubes are reinforced with steel ribs, consisting of wire rings welded and worked into the material, and spaced 9 in. apart. For the 60 in. × 40 in. and 54 in. × 36 in. tubes the rings are ⅜-in. dia., for smaller sizes ¼ in. dia. The tubes are made in 3-ft. lengths, and are jointed in cement, the joints being as shown in *Figs.* 2, 3, 4, 9.

The thickness of 60 in. × 40 in. pipes is 4 in., and these each weigh one ton. The smaller sizes of pipes are of the following thickness :—

EGG-SHAPED TUBES

Internal Measurements	Base	Thickness	Per Ton
in.	in.	in.	ft.
54 × 36 ..	22	4	3
48 × 32 ..	20	3½	4½
45 × 30 ..	18	3	4¾
42 × 28 ..	17	3	5½
36 × 24 ..	15	2½	7
30 × 20 ..	12	2¼	9½
27 × 18 ..	11	2	11½
24 × 16 ..	10	2	13½
21 × 14 ..	8½	1¾	17½
18 × 12 ..	7½	1¾	20

CIRCULAR TUBES

Diameter	Thickness	Per Ton
in	in.	ft.
48	3½	3¾
42	3	5
36	2½	7
33	2½	7¾
30	2½	8¾
27	2	12
24	2	13½
21	1¾	18
18	1½	24
15	1½	29
12	1¼	40

Other firms have supplied concrete pipes for sewers in this country. Among these might be named The Imperial Stone Co., Ltd., whose pipes vary from 15 in. to 18 in. dia., and have been laid in many towns. The pipes manufactured by this firm are circular in section and are reinforced by steel ribs.

Conclusion.—The author would conclude by saying that it is his opinion that concrete tubes, both circular and egg-shaped, are eminently suitable for use as main sewers and storm-water drains, and that he is confident that the time is not far distant when they will be used by engineers almost exclusively in place of glazed sanitary pipes and brick sewers for all sewers 6 ft. and less in diameter.

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NOTES ON REINFORCED CONCRETE *versus* WOOD IN INDIA.

By Major A. H. D. RIACH, R.E.

Some of our readers in India and in the Colonies occasionally enquire as to the application of reinforced concrete to simple everyday purposes. They desire to have particulars of this application and also information as to the cost.

An interesting communication was presented some time back by Major A. H. D. Riach, R.E., and afterwards published in "The Royal Engineers Journal." Pressure upon our space prevented our dealing with it whilst this journal was a bi-monthly; accordingly we now publish an extract from Major Riach's communication, together with illustrations, for they deal in a most lucid manner with the method of applying reinforced concrete to the everyday purposes of India and some of our colonies.—ED.

THE use of reinforced concrete in lieu of steel, brick, and stone is rapidly becoming more general, but its advantage as a substitute for timber is, at first sight, less evident. As a general rule, good timber can be subjected safely to greater stresses, both in compression and tension, than armoured concrete, and the consequent greater dimensions required for members of this material, its great weight and the care needed in its manufacture, would appear to outweigh any arguments in favour of its adoption for beams, rafters, small posts, etc., in ordinary building construction, particularly when the adaptability of wood, and ease with which it can be worked, is taken into account.

In the new barracks at Jubbulpore Major Stokes-Roberts, R.E., has, however, taken the bold departure of making up (amongst other parts of the buildings) door frames, verandah rafters, battens, bressummers, pillars and pillar caps of concrete suitably reinforced, and finds that he has effected a large saving thereby.

The following notes, describing the methods and first results of a trial of the same material, now in progress in the barracks at Ahmednagar, may be of interest.

In the barracks first built the lintels were made of reinforced concrete, and the pillar bases and bedstones for trusses of plain moulded concrete blocks. Except for small areas of flat roofs, no other armoured concrete was introduced. The verandahs are roofed with tiles on wooden rafters, posts, etc. It is proposed to discuss in this article, however, the advantages of employing reinforced concrete in members usually made of wood.

Nature of Members Manufactured.—It was considered that no gain would result from the use of concrete rafters and battens on account of the largely increased dimensions necessary for these members. On the other hand, the posts, pillar caps, bressummers, and verandah wall plates needed little or no increase of dimensions, and these have, therefore, been made up as described and illustrated below. The standard spacing of verandah pillars was fixed at 9 ft. c. to c. (in lieu of 7 ft. 6 in., as hitherto adopted for timber), rafters being 3 ft. c. to c.

Materials Available.—An abundant supply of shingle of all sizes, from $\frac{3}{4}$ in. downwards, is available, and this forms an ideal aggregate, after washing and screening out all pieces below $\frac{1}{4}$ in. The sand available is poor, being round, friable, and hard to clean thoroughly, but in practice excellent results have nevertheless been obtained. The proportion of voids in the shingle ballast is low, and the quantity of mortar needed for a dense concrete is consequently less than the average. It has therefore been possible to reduce the proportion of sand to cement to below what is usually given, without increasing the cost of the concrete.

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Proportions for Concrete.—A concrete of 3 parts shingle, ½ part sand, and 1 part cement (by volume) has been used for pieces likely to be subjected to direct blows, *e.g.*, for posts for wire railings, or for chairs of verandah posts in barracks, and has proved exceedingly tough. For lintels and members not liable to direct shocks the proportion of 5 shingle, 1½ sand, and 1 cement has proved satisfactory.

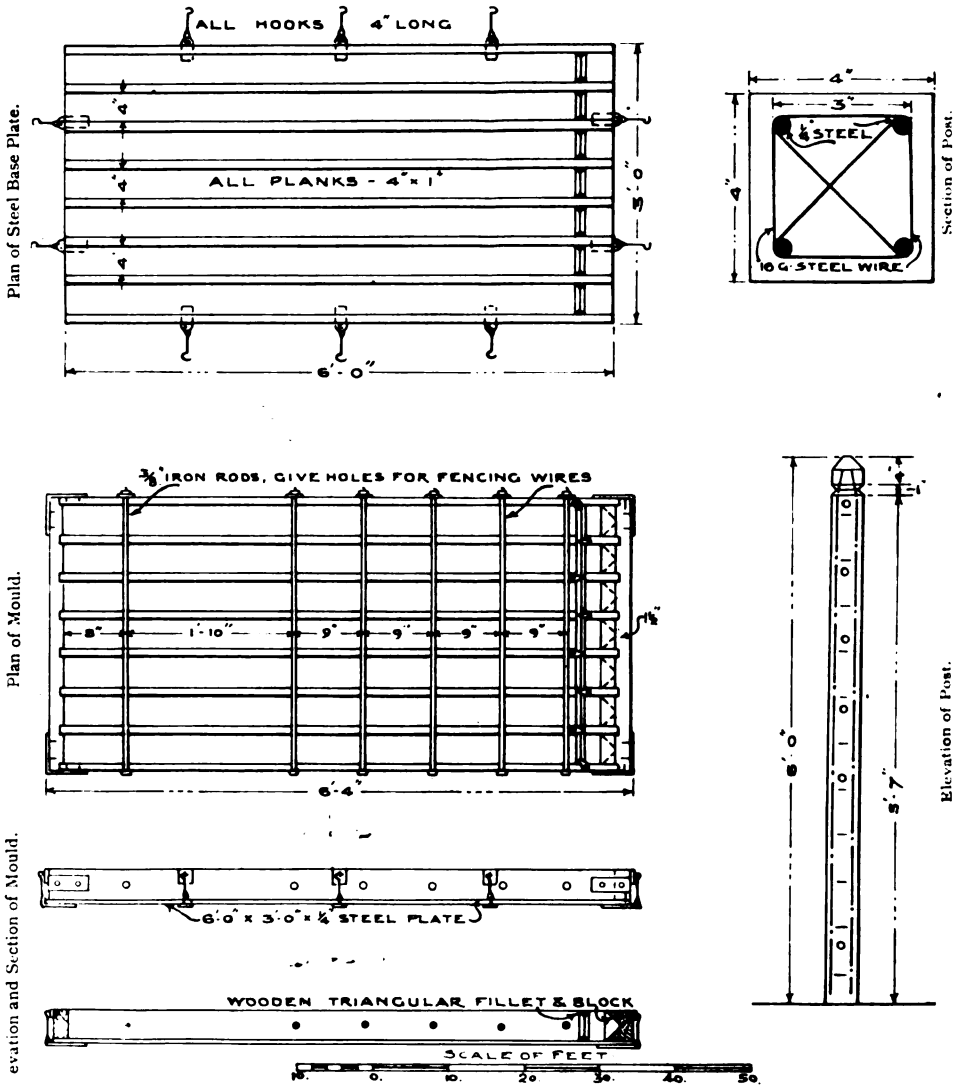

PLATE I. MOULDS FOR REINFORCED CONCRETE RAILING POSTS AT EAST RIDGE, AHMEDNAGAR.

With shingle up to 1 in. gauge, 5 shingle, 1½ sand, and 1 cement is used. For the work herein described the proportion adopted is 4 shingle, 1 sand, and 1 cement.

Consolidation.—The proportion of mortar being low, greater care in consolidating is taken than is customary in American and Continental practice. Every mould is

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well tamped as it is being filled, and when filled the surface is thoroughly rammed with the heaviest rammers of which the surface will admit. The result is a very compact concrete.

Proportion of Water.— Much depends on the right proportion of water being given. For clean surfaces and compactness the concrete is mixed so that while it looks only damp when being handled, yet, on ramming, water comes readily to the surface, and the whole becomes quaky. If the unrammed concrete is wet and pappy-looking,

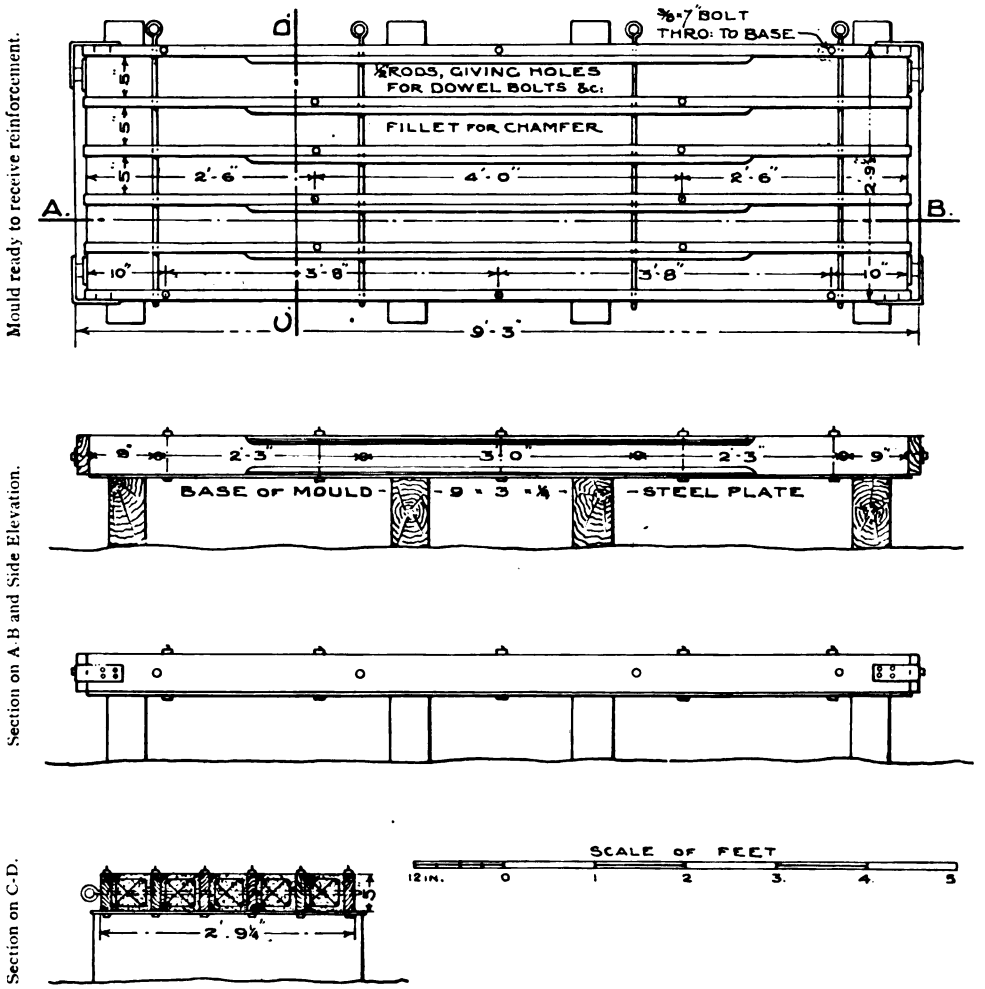

PLATE II. MOULDS FOR REINFORCED CONCRETE BRESSUMMERS.

it is not possible to effectively consolidate it in small moulds owing to the excessive sloppiness. In heavy masses (*e.g.*, bridges) more water is beneficial, as less ramming can be given than with small batches; in short, the more the ramming, the less the water.

Actually in practice proportions work out to:—

(*a*) For lintels, in moulds which can be rammed with heavy rammers, 12 gallons of water to 10 c.f. of completed product. This works out to shingle 5 c.f., sand 2 c.f., cement 1 c.f., water ·95 c.f.

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(*b*) For the posts, bressummers, etc., described in this article, 13 gallons of water to 10 c.f. of finished articles—*i.e.*, 4 c.f. shingle, 1 c.f. sand, 1 c.f. cement, ·83 cf. water (the amount of shingle used is almost exactly the cubic measure of the finished article, except with very rich mixtures).

Weight.—The average weight of the finished articles is 153 lb. per cub. ft. The weight of the ingredients is :—

Shingle, unrammed, dry	92 lbs. per c.f.
Sand, loose, dry	95 " "
Cement, loose	92 " "

Specific Gravity and Porosity.—The specific gravity of the concrete alone, varies from 2·44 to 2·62 (the higher figure being for a block of concrete of 1 cement, 1 sand, and 3 of hard black trap ballast). The porosity (*i.e.*, ratio of increase of weight after thorough wetting) from 1·6 to 3·6 per cent. This factor is relative, and not absolute, as the degree of dryness is a variable quantity, for in wet weather the increase in weight due to soakage of water will be less than in dry weather. It is given as affording some indication of the compactness or density and watertightness of the concrete. The porosity of samples of 1 :2 :4 cement concrete obtained elsewhere, and tested at the same time, varied from 5·2 to 8 per cent.

Armouring.—It is very convenient to make up the armouring as a skeleton, ready to drop into the moulds. The skeleton armour is shaken as the concrete is being filled into the moulds, to get the rods into correct position and well embedded. No rods have been found exposed when moulds are removed.

Moulds.—It has been found profitable in every way to manufacture the pieces in moulds with a large number of partitions (see Plate I., illustrating the moulds used for railing posts, and Plate II., those for bressummers). In every member, the armouring of which is unsymmetrical, the lower edges are chamfered, or the tops and bottoms of the pieces otherwise distinguished. The moulds are made of wood, carefully planed and sand-papered, and pickled in cocoanut oil for three days. The base plates consist of steel plates. Great care is taken with the fitting of the moulds, as it has been found that roughened and warped moulds give much trouble.

Oiling.—Before filling the whole is wiped over with a fairly dry oil rag, and no concrete ever sticks. The armouring is then placed in position (care being taken that no surplus oil is about to get on to the armourings), and the bolts to form holes for dowels, etc., are wiped over with the oil rag and fixed.

Treatment after Consolidation.—These bolts are turned as soon as the mass has been rammed, and are removed the following morning. The sides of the moulds can be removed after 24 hours, but otherwise the pieces are left untouched for 10 days under straw, which is kept well wetted. They are then removed and stacked, and kept wet for a further five days or more. It is most desirable to allow them to dry out in the shade. Sudden partial drying in the sun is liable to cause unequal shrinkage and hair cracks, which are unsightly and may cause weakness. This applies especially to slabs and thin pieces, and particularly in dry weather. Ten days on their beds is laid down; if handling earlier is unavoidable it must be done with the greatest care.

Touching up and Surfacing.—Surfacing, if required, is done on the tenth day (exposed surfaces can be surfaced on the second day). The pieces come out with clean surfaces and sharp arrises, and, except for the sake of appearance, they need no touching up other than filling in a few holes left by excess water, or touching up chance injuries; in fact, the surfaces are so clean that they have to be roughened before sand rubbing will adhere.

Sand Rubbing.—The sand rubbing is done by applying and rubbing in with wooden floats the thinnest possible skin of specially chosen 2 parts sand and 1 part cement. Care is taken to avoid streakiness in this coating. Trowels are unsuitable as they give a polished surface. The difficulty of making the sand coat adhere is a defect to be guarded against.

Ornamentation.—The simplest possible design is followed, viz., plane surfaces with plain chamfers, the members being treated as cut-stone. It is considered that in barracks, otherwise plain and solid, the addition of anything in the nature of florid embellishments would be out of place. At the same time ornament can be applied with little extra trouble if desired.

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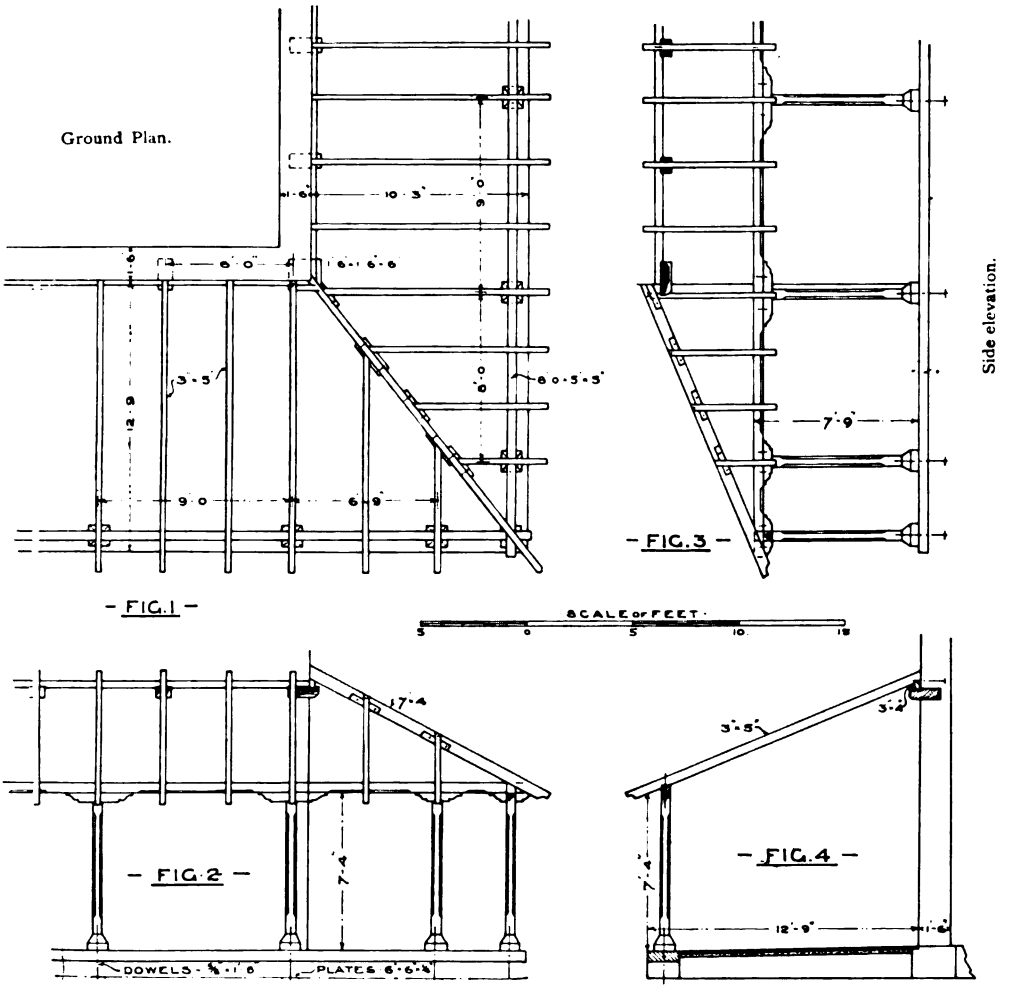
Conditions of Work and Labour Employed.—The work is done as far as possible under cover. Two trained masons with a few coolies are constantly employed; they fill three or four moulds daily, empty a corresponding number which have lain for ten days, and surface and water as required, in rotation. The armouring is made up into skeletons beforehand by one or two khalassies. A carpenter is employed,



Front elevation.

Cross Section on A-B.

PLATE III. PLAN OF VERANDAHS, S.W. CORNER OF NO. 21 MARRIED QUARTERS, NEW B.I. LINES, AHMEDNAGAR.

if specially required, for alterations or repairs to moulds. In this way no labour is wasted, and supervision is reduced to a minimum, a most important matter when the quality and trustworthiness of the product depends on reliable work efficiently supervised.

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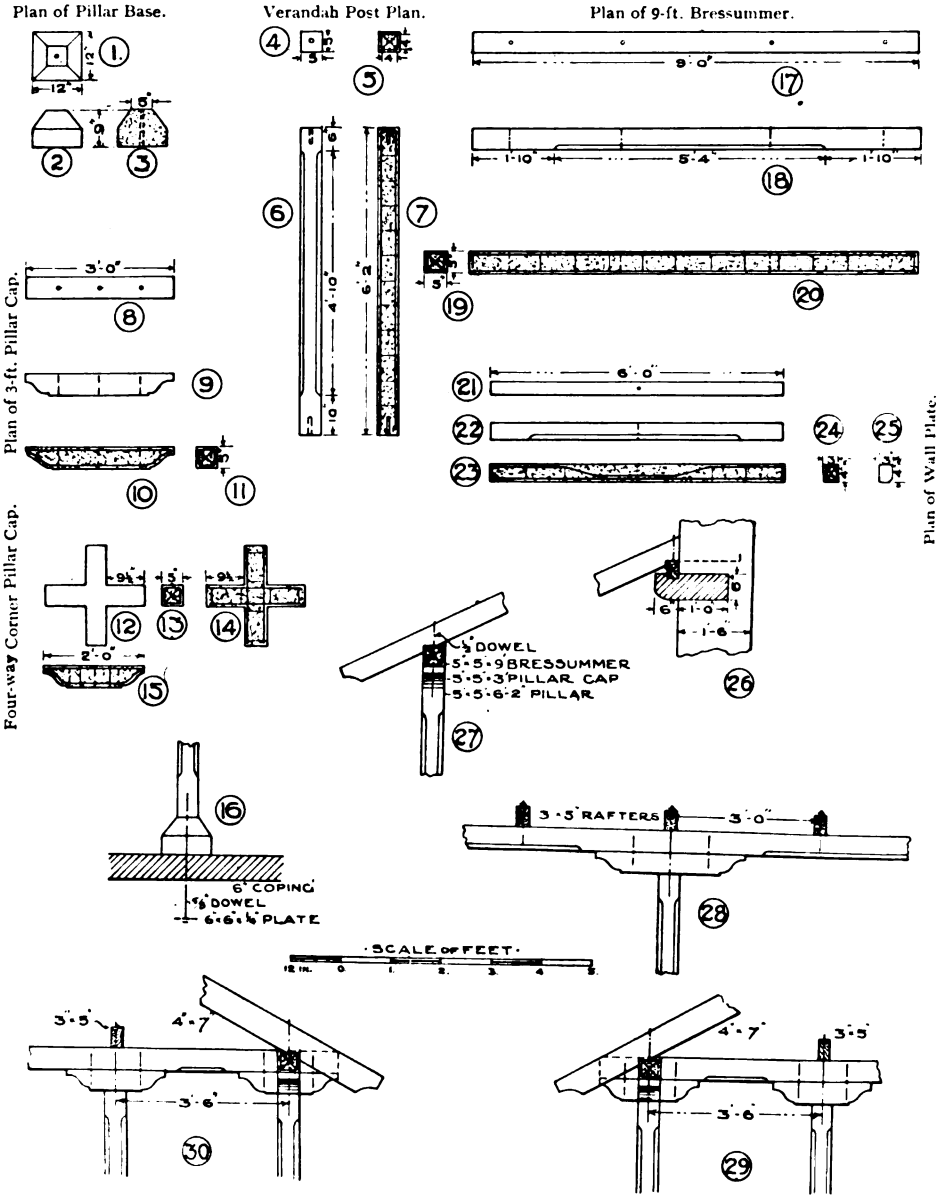

PLATE IIIa.

Reference Numbers on Plate IIIa.

Nos. 1, 2, 3—Plan, Elevation and Section of Pillar Base.
Nos. 4, 5, 6, 7—Plan, Section, Elevation and Section of Verandah Post.
Nos. 8, 9, 10, 11—Plan Elevation, Sectional Elevation and Section of 3 ft. Pillar Cap.
Nos. 12, 13, 14, 15—Plan, Section, Sectional Plan and Sectional Elevation of Four-way Corner Pillar Cap.
No. 16—Detail at Pillar Base.
Nos. 17, 18, 19, 20—Plan, Elevation, Section and Sectional Elevation of 9 ft. Bressummer.
Nos. 21, 22, 23, 24, 25—Plan, Elevation, Sectional Elevation, End Section and Centre Section of Wall Plate.
No. 26—Section at Wall Plate.
Nos. 27, 28—Section and Elevation at Pillar Cap and Bressummer.
No. 29—Side Elevation at Corner.
No. 30—Front Elevation at Corner.

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Cost. — The following details show the cost of the work; they are actual figures, not specially selected :—

I. 112 RAILING POSTS * OF 1 CEMENT, ½ SAND, 3 SHINGLE, EACH 6 FT. BY 4 IN. BY 4 IN. = ⅔ C.F. TOTAL, 75 C.F.

	R.	a.	p.
72 c.f. screened and washed shingle at R.3 8a. per 100 c.f.	2	8	3
24 c.f. cement at R.2 per c.f.	48	0	0
12 c.f. sand, washed, at R.3 per 100 c.f.	0	5	9
3 cwt. ¼ in. round steel, mild, at R.8 per cwt.	24	0	0
1 cwt. wire, 150 lbs. to the mile, at R.14 per cwt.	14	0	0
Labour	28	0	0
Straw, oil, etc.	1	2	0
Total	R.118	0	0

Cost per c.f., R.1 9a. 2p., exclusive of surfacing.

These are for use in lieu of jarrah wood posts of the same dimensions, costing R.2 per c.f., unwrought. There is a gain of, say, 8a. per finished post in favour of concrete. The resulting railing is neat and satisfactory.

* As *Plate* 1.

II. REINFORCED CONCRETE WORK IN PILLARS, BRESSUMMERS, CAPS, GATE POSTS, ETC., OF 1 CEMENT, 1 SAND, AND 4 SHINGLE.

Work Done from January 21st, 1908, to February 5th, 1908.

36 verandah pillars, 6 ft. 2 in. by 5 in. by 5 in.	= 38 c.f.
20 bressummers, 9 ft. by 5 in. by 5 in.	= 31 ,,
36 caps, 3 ft. by 5 in. by 5 in.... ...	= 19 ,,
6 gate posts, 6 ft. by 5 in. by 5 in. ...	= 6 ,,
3 struts to do., 6 ft. by 4 in. by 3 in.	= 2 ,,
	96 c.f.

Labour Employed.

	R.	a.	p.
2 masons, 16 days at 14a. ...	= 28	0	0
4 coolies, 16 days at 4a.	= 16	0	0
2 women do., 16 days at 2a. 6p.	= 5	0	0
1 khalasee, 16 days at 8a. (wiring steel work)	= 8	0	0
¼ carpenter, 16 days at R.1 ...	= 4	0	0
½ bhisti, 16 days at 10a.	= 5	0	0
	66	0	0
Deduct :—			
Labour value of 24 pillar bases and 24 bedstones made by above labour = 48 at 3a.	= 9	0	0
Total labour ...	R.57	0	0

Materials.

	R.	a.	p.
96 c.f. shingle at R.3 8a. per 100 c.f.	= 3	5	9
24 c.f. sand at R.3 per 100 c.f. ...	= 0	11	6
24 c.f. cement at R.2 per c.f. ...	= 48	0	0
Round steel, mild, 6 cwt. 3 qrs. 23 lbs., at R.8 per cwt. ...	= 55	10	3
Steel wire, 2 qrs., at R.12 per cwt.	= 6	0	0
Cocoanut oil, 3 lbs., at 4a. per lb....	= 0	12	0
Grass, etc., say	= 0	8	6
Total material	R.115	0	0
Total labour and material	R.172	0	0

Rate per c.f. = $\frac{172}{96}$ = R.1 12a. 8p. per c.f.

P.S.—The above includes labour and material used in sand rubbing the surfaces.

Issue Rate. — The labour charges tend to get lower as the workmen become more expert. The issue rate of the members described, *including moulds*, has been fixed at R.2 per c.f.

Including the comparatively simple lintels, with their lesser proportion of cement and the pillar bases which have no armour, an all-round rate of R.2 per c.f., *fixed in position*, amply covers the cost of the work. In the comparative statement below this rate has been taken.

Comparison with Cost of Teak.—Comparative cost of teak and reinforced concrete for verandah 100 ft. long.

(*a*) Mangalore tiles on battens 1 in. by 1½ in., rafters 3 in. by 5 in., bressummers 5 in. by 4 in., pillar caps 2 ft. by 5 in. by 4 in., posts 5 in. by 5 in. at 7½ c. to c., pillar chairs of concrete blocks, wall plate 3 in. by 4 in., all woodwork teak.

Rupee = 1s. 4d. 16 annas in a rupee. 4 pice in one anna.

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Detail of cost of above :—

(*a*) 14 concrete chairs 1 ft. by 1 ft. by $\frac{3}{4}$ ft.	= 9·33 c.f. at R.2 c.f.	= R. 18·66
14 posts, teak, 6 ft. 6 in. by 5 in. by 5 in.	= 15·80	
14 pillar caps, teak, 2 ft. by 5 in. by 5 in.	= 3·89	
100 ft. bressummer, teak, 5 in. by 4 in.	= 13·89	
100 ft. wall plate, teak, 3 in. by 4 in.	= 8·33	
	41·91 at R.3 12a. c.f.	= R.157·16
14 holding-down bolts, complete, at $6\frac{3}{4}$ lbs.	= $94\frac{1}{2}$ lbs.	
14 straps for posts, complete, at $4\frac{1}{2}$ lbs.	= 63 ,,	
34 rafter cramps, complete, at 2 lbs.	= 68 ,,	
34 connection rafter to wall plate at $\frac{1}{3}$ lb.	= $33\frac{1}{3}$,,	
	$258\frac{5}{8}$ lbs. at R.21 cwt.	= R. 48·56
	Total ...	R.224·38

(*b*) Mangalore tiles on battens 1 in. by $1\frac{1}{2}$ in. and rafters 3 in. by 5 in. of teak, bressummers, reinforced concrete, 5 in. by 5 in., pillar caps, reinforced concrete, 3 ft. by 5 in. by 5 in., posts, reinforced concrete, 5 in. by 5 in. at 9 ft. c. to c., pillar chairs of concrete blocks. wall plate, reinforced concrete, 3 in. by 4 in.

(*b*) 12 concrete chairs 1 ft. by 1 ft. by $\frac{3}{4}$ ft.	= 8 c.f.	
12 posts, reinforced concrete, 6 ft. 2 in. by 5 in. by 5 in....	= 12·85	
12 pillar caps, reinforced concrete, 3 ft. by 5 in. by 5 in....	= 6·25	
100 ft. bressummer, reinforced concrete, 5 in. by 5 in. ...	= 17·36	
100 ft. wall plate, reinforced concrete, 3 in. by 4 in. ...	= 8·33	
	52·79 at R.2	= R.105·58
12 anchor dowels for chairs, complete, at $4\frac{1}{2}$ lbs.	= 52 lbs.	
12 dowels for posts $\frac{1}{2}$ in. by 9 in. at $\frac{1}{2}$ lb.	= 6 ,,	
3 by 12 dowels pillar caps $\frac{1}{2}$ in. by 9 in. at $\frac{1}{2}$ lb.	= 18 ,,	
22 dowel bolts for rafters with nuts $\frac{1}{2}$ in. by 10 in. at $\frac{3}{4}$ lb.	= 15 ,,	
12 ditto with turned ends at $\frac{3}{4}$ lb.	= 10 ,,	
34 connections wall plate and rafter at $\frac{3}{4}$ lb.	= 29 ,,	
	130 lbs. at R.21 cwt.	= R. 24·38
	Total ...	R.129·96
	Saving ...	R. 94·42

Practical and Financial Advantages.—These figures show a saving, bulk for bulk, in favour of reinforced concrete of R.1 12a. per c.f., or, in the case of the verandah, a saving of 15a. per r.f. of verandah, due to this and the increased spacing of the posts permissible with concrete bressummers. Adding the cost of painting, initial and recurring, the saving comes to R.1 per r.f. of verandah.

It is therefore evident that when it is found possible to run the manufacture of reinforced concrete under proper supervision, and with a sufficient output to pay for the moulds and other initial expenses, a very substantial gain can be realised by employing this material extensively in place of teak or other expensive timber. Once erected, the members need no maintenance and are practically indestructible.

Conclusion.—As already stated, work of this nature should not be undertaken unless it can be effectively looked after. Also it must be remembered that every piece has to fit correctly into the place it is required to occupy, so moulds, etc., must be standardised. The material can be cut with care, but all cutting and dressing should be avoided as far as possible, as it takes much time, and the concrete may be damaged. Further, it is necessary to handle the pieces with somewhat greater care than is usual in fixing carpenter's work, for it is not easy to neatly repair chipped corners, and cracks, even if they do not materially reduce the ultimate strength, are unsightly.

The decision to extend the application of the material to buildings still to be put in hand finds ample justification in the confidence and experience already gained.

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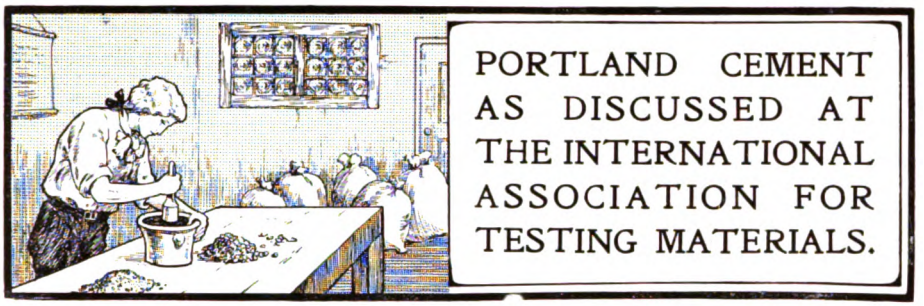

As indicated in the editorial columns of our October issue, various papers and reports on Portland Cement were presented at the recent Copenhagen meeting of the International Association for Testing Materials.

The more important of these papers will be published in this journal, not only as valuable contributions to a much discussed subject, but also as of special utility for reference purposes.—ED.

INTERNATIONAL CONGRESS FOR TESTING MATERIALS.

The following paper was presented on the occasion of the International Congress on Testing Materials at the meeting of Section B, which dealt with concrete, reinforced concrete and Portland cement. Papers dealing with Portland cement were taken on Wednesday, Thursday and Friday, September 8th, 9th and 10th, Captain Grut, of the Danish Royal Engineers, acting as local Chairman and the Hon. Foreign Presidents of the section also being present.

UNIFORM TESTS OF HYDRAULIC CEMENTS BY MEANS OF PRISMS—STANDARD SAND.

Report of Chairman of the Committee, Professor F. SCHÜLE, Zürich.

THE ascertainment of the strength of the hydraulic cements for the determination of their comparative qualities is in general achieved by means of the subjection to tensile and compression tests of test-samples consisting of mortar of the consistency of 1 part cement to 3 parts standard sand together with a varying quantity of mixing-water, either pressed together by hand or rammed by machine power, according to the country in question.

After the Congress held in Buda-Pest in 1901 two referees were nominated for the study of the question of standard sand, and at the Brussels Congress the author of this report had an opportunity of discussing the properties of sands of the kinds that come in question for the testing of hydraulic cements in a fairly thorough manner. Subsequently a committee was constituted in the spring of 1907 in the following manner :—

Chairman : *Prof. F. Schüle*, Zürich.

R. Feret, Laboratoire des Ponts et Chaussées, Boulogne-sur-Mer (France).

A. Mesnager, Laboratoire du Conservatoire des Arts et Métiers, Paris (Leduc).

Prof. Dr. Ing. A. Martens, Prof. M. Gary, Kgl. Material-Prüfungsamt, Gr.-Lichterfelde.

Dr. Framm, Laboratorium des Vereines deutscher Portland-Zementfabrikanten, Karlshorst bei Berlin.

Prof. Schüle, Eidgenössische Material-Prüfungsanstalt, Zürich.

E. Camerman, Laboratoire de l'arsenal de l'Etat Belge, Malines.

R. L. Humphrey, Materials Testing Laboratory, United States Geological Survey, Philadelphia.

Prof. Dr. Ing. N. Belelubsky, Prof. Bogdansky, Mech. Laboratory of the Imperial Institute for Road Building, St. Petersburg.

Prof. B. Kirsch, Mechanisch-technisches Laboratorium der technischen Hochschule, Wien.

Mayntz Petersen, Danish State Testing Laboratory, Copenhagen.

Prof. S. Canevazzi, Ecole d'applications pour les Ingénieurs, Bologna.

L. Bienfait, Material-Prüfungstalt von Bienfait und Koning, Amsterdam.

Most of the testing laboratories declared their willingness to undertake investigations, the results of which are put together in the following report and give good hope that a simple, exact, and uniform method for the testing of the strength of hydraulic cements will be attained in the near future.

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The process applied in the strength-tests of hydraulic cements has in each country been the outcome of long-continued investigations, and it is not likely that a considerable revolution in favour of the approval by our Association of a method used by one particular country will ever become possible. Notwithstanding this, however, there are numerous cases in which it would be of advantage to obtain strength-values of the kind, which could be directly compared one with another, in whatever testing-laboratory or country such tests might be made.

In view of this the undersigned made the proposal at the Brussels Congress that a general agreement be come to, that for purposes of comparison the strength of hydraulic cements be determined by means of 4 by 4 by 16 cm. prisms of mortar of 1 :3, in the manner in which such have for years been applied by Mr. Feret in the Laboratoire des ponts et chaussées, in Boulogne-sur-Mer, the sand there in use being a quartz-sand obtained by the aid of sieves of 64 and 144 meshes to the sq. cm. respectively; the prisms here to be first submitted to a bending test, after which the halves of each broken test-sample were to undergo the compression test.

In view of its uniformity and of the control exercised in its production the German standard-sand of Freienwalde was recommended as the most suitable sand material.

PROPOSED INVESTIGATIONS.

The investigations thereupon proposed were the following :—

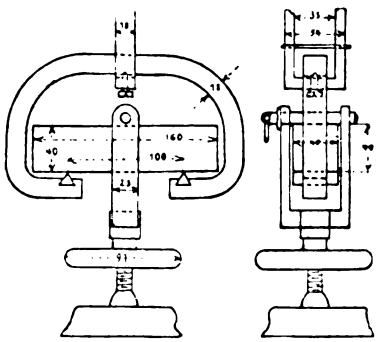
(a) Preliminary Experiments.—Parallel experimental tests lasting for seven and twenty-eight days respectively on a few cements to be made on the prism method and in the manner usual in each laboratory, with the standard sand of the respective country and with German standard sand from Freienwalde.

(b) Comparative Experimental Tests. — The testing of two Portland cements which are to be sent from a central point to all testing establishments that agree to take part in these tests, by the method usually employed in each particular establishment and by the process with prisms and German standard sand. The tests would take place after periods of seven and twenty-eight days.

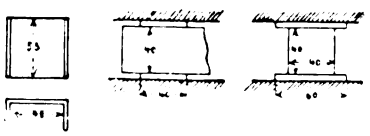
THE ZURICH MODEL.

The circular containing these proposals was accompanied by a description of the method in use in the Federal Testing Laboratory in Zürich for the production and testing of standard mortar prisms of 1 to 3 in plastic consistency.

Bending Tests. — At Zürich the bending is tested by the Michaelis apparatus, which, in place of the grips usually employed for octagonal block samples, is provided above with a stirrup with two knife-edges 10 cm. apart and below with a small frame with a removable cross-bar, as in the accompanying drawing. The prisms are introduced into the stirrup in the horizontal position and between the cheeks of the frame. The iron cross-bar of the lower frame is then inserted and brought into the middle of the field of support.



ARRANGEMENT FOR BENDING TESTS.



PLATES AND ANGLE IRON FOR COMPRESSION TESTS.

Half of the prisms are laid on a press between steel plates 4 cm. in breadth. To ensure that the plates lie exactly one above the other an angle iron is made use of, as shown in the drawing.

Mixing of the Mortar. — For the simultaneous production of 6 prisms 2·700 kgs. of standard sand and 0·900 kgs. of cement are simultaneously mixed dry in a shallow vessel, after which water is gradually poured in and the mass is then vigorously worked through by hand with the trowel for from three to five minutes.

For the plastic consistency the mortar requires from 1½ to 2 per cent. more water than for the usual normal consistency for ramming. According to experiments made the quantity of water required can also be determined by the number of blows (35 to 45) required to cause water to trickle from a cube, rammed in the apparatus.

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Production of the Prisms.—Each division of the 6-part mould is at once half filled, so that the water does not flow from one compartment into the others during the process of ramming.

The easy and rapid ramming operation is effected by hand with a pestle or rammer 1 kg. in weight and 3 by 3 cm. in section, the ramming effect being produced merely by its own weight after being raised from 0·5 to 1 cm.

After the surface of the mortar has been scraped off, there comes the second filling of all the compartments, which after ramming, must be sufficient in quantity to completely fill the mould so that some material has to be removed; the water then collects on the surface. After this the mould is shaken a few times on the moulding table and its surface smoothly scraped off with a straightedge.

Method of Keeping the Samples.—The samples remain in their places till the material sets, that is to say until they can be easily removed from the mould; in the case of Portland cement this condition is generally reached in about 24 hrs.; the prisms are kept on a brass plate in the moist closet for about 8 to 12 hrs. more, and are then immersed in water until just before the test.

Conduct of the Test.—The bending test is conducted in such a manner that the part of the prism which was uppermost in the moulding process is also uppermost in the stirrup. The weight of the shot-tray multiplied by 11·7 gives the bending-strength, which is equal to twice the tensile strength.

The compression test on each half prism is made by the canting over of the prism through an angle of 90°, so that the pressure is applied in a direction lateral to the ramming, that is to say, the two sides adapt themselves better for the distribution of the pressure on account of their smooth plane surfaces. The mean of the results with the two halves of a prism is set down as the compression strength.

Of the six values given by a series, the arithmetical mean of the four best ones is looked on as the authoritative result.

M. FERET'S VIEWS ON THE ZURICH TESTS.

The procedure thus initiated at Zürich obtained the approval of most of the testing establishments, but on the other hand several important observations were submitted by Mr. Feret, which in the main bore reference to the following points:—

Sand.—(a) The sand of uniform size of grain limited by the 64 and 144 meshes is not very suitable for the production of plastic mortars; for, according to Mr. Feret, the water mixed with cement will easily flow between the grains, so that the mortar does not become homogeneous. The mixed grain sand would not be subject to the same disadvantages, and a mixture would not be incompatible with the use of the Freienwalde sand, which in its crude condition contains about 50 per cent. (by weight) of grains limited in size by perforated plates with holes of 2, 1·5, 1, and 0·5 mm. respectively.

Mortar.—(b) One of the advantages of the plastic mortar consists in the independence of special machinery, which it gives; on this account it is illogical to determine the quantity of the mixing water by means of the ramming apparatus.

The definition of a uniform consistency is one of the chief difficulties attending the use of such mortar, and it would be desirable, that the determination of the quantity of water that is necessary for the attainment in every case of mortars of the same consistency with every cement should be referred to the Committee as one of their most important tasks.

Ramming.—(c) It would be desirable that the degree of rammability of the mortar in the moulds should be determined. Every laboratory was invited to make trial of the proposed method, to improve it, and to propose alternatives.

Compression and Shearing Strains.—(d) Mr. Feret takes exception to the bending test with load concentrated in the middle, on the ground that the section at this point has to take compression and shearing strains in addition to the bending strains proper, and he declares himself in favour of the employment of symmetrical loads, which, in the field in which the fracture occurs, gives a constant bending moment without the co-operation of the shearing force. The arrangement advocated by Mr. Feret is to be found in his book, "Etude expérimentale du ciment armé," and was explained at the Brussels Congress.

Bending Test.—(e) In connection with the bending test, Mr. Feret would give the preference to the application of the power against the lateral surfaces of the prism, since during the moulding process the uncovered surface is not so regular

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as the three others, and moreover has not always the same composition as the rest of the piece on account of the action of the outer air during setting.

Proportion between Bending Strengths.—(f) It would be illusory to attempt to discover a definite proportion between the bending strengths obtained by the new method and with plastic mortar and the tensile strengths with rammed mortar, which may have been determined by the methods at present in use in the various laboratories. Such experiments have always shown that no proportionality exists, which is an almost unavoidable consequence of the difference between the two methods.

These observations, which are communicated to the members of the Committee, have contributed in an effective manner to the more exact determination of the programme of the operations. The preliminary tests have, notwithstanding this, been carried out in the sense in the first circular and in accordance with the method therein described, for the following reasons :—

REASONS FOR THE ZURICH METHODS BEING APPLIED.

Methods of Testing.—A method for the testing of hydraulic cements is in various respects arbitrary. This is the case with all tests which give comparative and not absolute results.

Committee No. 42 wishes to try to give uniformity to the method for the comparison of the strength values determined in different countries and different laboratories. The method is not intended to replace older ones, that are exactly marked out, but are different in the various countries. This uniform method is to be specially distinguished by its simplicity.

For this reason the particular sand was proposed as a standard, which is obtained between sieves of 64 and 144 meshes—that of Freienwalde in particular. Between this sand and that which includes 3 sizes of grain (sieve with holes of 2, 1·5, 1, and 0·5) in equal parts by weight, there is a difference of 6 per cent. in the unfilled spaces (interstices). It is scarcely probable that this difference is sufficiently considerable to characterise the one mortar of 1 to 3 as homogeneous and the others as non-homogeneous. The difficulty of obtaining the fine sand (0·5 to 1 mm.) in a homogeneous state, and of always mixing the three sizes of grain in the same given proportion for test-samples that are to be exactly alike, is greater than that which arises from the larger hollow spaces referred to above.

Sand. — The investigations which have been made in countries other than France with mixed-grain sands did not show favourable results for such sands; for this reason it seemed advisable that the sizes of sand-grain which are in pretty general use should be adhered to.

Water.— The determination of the proportion of water which is suitable for the plastic mortar is one of the greatest difficulties. Most of the testing laboratories are in possession of ramming apparatus for the mortar-tests (either on the Böhme or on the Klebe-Tetmajer system). It is possible, by the aid of this apparatus, to ascertain the mechanical work applied in ramming, and in this way to determine the proportion of water necessary for the attainment of a given consistency of the mortar. After a few experimental tests in this direction, it will be possible to fix a proportion between the quantity of water used for plastic mortar of 1 to 3 and the quantity which corresponds with the standard consistency of pure cements.

The ramming test with the machine is given as a fairly practical and provisional means of determining the suitable quantity of water.

Bending Tests. — In the case of bending tests which give a constant moment in the central field, the shearing force is, indeed, avoided, but at the points in which the forces act the bending moment and the shearing force are always present. If the shearing force exercise an unfavourable influence on the strength, fracture will occur under the points of application of the load, and not between these points. Should fracture occur between these points, this means that the shearing force does not act in a disadvantageous manner, or that there is a weak place between the points of application of the load on the test sample, so that the result will be more likely to be an abnormal one. The arrangement which is applied in the Federal Testing Laboratory in Zürich has produced good results. A comparison between the method with constant moment and that with concentrated load will show which of these gives the more consistent results; the better one should then be applied. The interesting results contained in Mr. Feret's work on reinforced cement are not at variance with the foregoing remarks, since the experiments with constant bending moment and those with

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concentrated load showed the same regularity, the figures obtained by the first-named method, however, being smaller by 14 per cent. than those by the second one; this cannot be regarded as an advantage.

PRELIMINARY TESTS.

Preliminary Experimental Tests.—The preliminary experimental tests set forth in my original circular (1907) have been carried out in several testing laboratories, and up to January, 1908, I received the results from the laboratories of Karlshorst (Dr. Framm), Bologna (Professor Canevazzi), Amsterdam (Eng. Bienfait), Vienna (Prof. Kirsch), and Zürich.

The tests were made with Portland cement in accordance with the suggestions made, and at the same time also in accordance with the methods of testing usually employed in the respective laboratories.

Have the first experiments given a favourable result?

Is it necessary to improve or modify the proposed prism method?

The results obtained enable a preliminary answer to be given to these questions.

The absolute amount of the strength is not taken particularly into account, and is only given in connection with the results of the seven day and twenty-eight day tests of the rammed moist mortar, in order to compare the relative strengths that are obtained when the strength of earth-moist mortar is taken as the unit.

It is to be observed that bending and tensile tests do not necessarily give the same proportion between the strengths as compression tests, since, in the first case, half the bending strength is compared with the tensile strength, while, in the second, two compression strengths are compared.

The latter proportion is, in general, somewhat less than the former one. The figures of comparison vary also, according to the quality of the cement submitted to test and according to the length of time during which the test-samples have been kept. The comparative figures from the experimental tests given are the following :—

Running No.	Laboratory	Standard Sand	Tensile strength after 7 days	Tensile strength after 28 days	Compression strength after 7 days	Compression strength after 28 days
1	Karlshorst	German	0·61	0·68	0·62	0·67
2	Amsterdam	,,	0·79	0·77	0·70	0·70
3	Bologna	,,	0·55	0·60	0·33	0·37
4	,,	Italian	0·46	0·55	0·38	0·46
5	Zurich	Swiss	0·82	0·88	0·66	0·81
6	,,	German	1·05	1·10	0·87	1·02

Results.— The results of series 1 and 2 show a satisfactory agreement; series 3 and 4 give for the compression strengths in particular a very small proportion figure for the plastic mortar, as compared with that for the rammed earth-moist mortar. This is attributable to the comparatively important differences between the individual strengths of the plastic mortars, which will be apparent from a comparison between the mean values for the two simultaneously tested groups. The series 5 and 6 differ from the rest in the high strength values obtained with plastic mortar. This result may be due to a longer duration of the ramming process and to the care bestowed on the attainment of equal app. spec. gravity.

The German standard sand has grains of uniform size and rounded form, like the Swiss standard sand. With a plastic mortar hand-ramming enables the sand grains to assume positions towards each other that are more favourable to the attainment of high degrees of strength than is the case when the ramming is done by machinery.

In 1907 Professor Canevazzi published a more detailed account of the extensive tests made in the laboratory, of which he is manager, in Bologna under the title "Contributo a studi sperimentali di provo per gli agglomeranti idraulici."

Compared with those attained in other laboratories the strengths determined by him showed considerable differences, and tests were accordingly made by Mr. Feret and Mr. Canevazzi with four series of six prisms each, which were made in Bologna, two of the series of tests being conducted in the latter town and the other two in Boulogne-sur-Mer. From these tests it appeared, not only that the app. spec. gravity of the prisms of one and the same series showed rather considerable differences, but also that the means of the two series varied considerably one with the other :—

Series 2 : 2,171—2,215
Mean : 2,195

Series 3 : 2,202—2,233
Mean : 2,217

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The differences between the strengths obtained in the two laboratories do not exceed those which showed themselves between two series tested in one and the same laboratory. Finally, when the means of the differences between the individual tests of the prisms or half prisms of each series are calculated out and general means of the strengths thus given are taken, it appears that their values expressed as percentages of such mean strengths do not show any considerable difference between one laboratory and another as regards the bending tests, but that the compression test results are much higher in Bologna (23 and 16 per cent.) than in Boulogne-sur-Mer (4 and 5 per cent.). This difference is chiefly due to the circumstance that, while the apparatus for the bending test was the same in both laboratories, for the pressure tests a universal testing-machine was employed in Bologna, which was not so well adapted for these particular tests as the machine made use of in Boulogne-sur-Mer.

Conclusions.— To sum up the foregoing, the results as a whole cannot be regarded as satisfactory. Although the various testing establishments agree in regarding the prism method as convenient and practical, it is desirable that its improvement be sought after, so that results that are in better agreement with each other may be obtained.

The chief differences are probably due to the circumstance that in the description of the process applied in Zürich we omitted to emphasise the importance of the testing of the app. spec. gravity of the prisms, which, in the application of the ordinary method with octagonal and cube-shaped samples, is always attended to.

UNIFORM PRODUCTION OF PRISMS.

Prisms.— Mr. Frey, manager of the Vigier Cement Works, at Luterbach, has endeavoured to solve the problem of the uniform production of prisms, and has arrived at a satisfactory result by the expedient of filling a mould of the same content as that of a prism with standard mortar of plastic consistency, and seeking to attain the app. spec. gravity of 2·17 to 2·18 by a suitable method of ramming. This preliminary experiment fixes the quantity of the mixing water and the kind of hand work that are to be applied in each case. If the app. spec. gravity be too large, a little water must be added; if it be too small, some of the water must be removed. With a app. spec. gravity of 2·17 the mortar is very plastic, the proportion between the tensile strengths being 0·50 and that between the compression strengths 0·44 to 0·46. The individual results of tests on prisms made by this method agree one with another.

The various tests made in the Federal Testing Laboratory in Zürich have given a similar result. With a Portland cement which shows 9½ per cent. of water for standard mortar rammed in an earth-moist condition (with Swiss sand) and 11 per cent. for plastic mortar, made by the method described in my circular, a mould of 4 by 4 by 16 cm. can be filled with 575 gr. of mortar, corresponding with an app. spec. gravity of 2·25. This figure may be attained by suitable ramming. A test with 1 or 2 prisms will show what manner of ramming is suitable, and this must then be adhered to as far as possible for all the prisms.

If a low app. spec. gravity be resorted to, such as that of 2·17 of Director Frey, the differences in the hand work may, on account of the greater plasticity of the mass, be less considerable; but on the other hand it is to be feared that the mortar will be less homogeneous.

Preliminary tests appeared to show the importance of improving the method in order to obtain satisfactory results. According to the proposal of Mr. Frey, Manager of the Vigier Cement Works, at Luterbach, a solution was to be found in the expedient of keeping the volumetric weight of the fresh mortar at from 2·17 to 2·18 under all circumstances. According as the volumetric weight obtained by the first experiment turned out too great or too small, the mortar could, in order to obtain the typical figure, be mixed with a somewhat greater or somewhat smaller quantity of water.

The tests conducted in Zürich had led to the recommendation of this method, but to the proposal of a higher figure for the volumetric weight, which stands in connection with the circumstance that our staff are accustomed to a ramming process of longer duration, Mr. Feret has tested this method and put his conclusions together in the form of a notice, which bears the title: "Vérification de la méthode de Monsieur Frey," and which was distributed among the members of the Commission in April, 1908. The principal contents of this notice are here given :—

M. FREY'S FINDINGS.

A process of such simplicity, which simultaneously solves the two principal difficulties that stand in the way of the general application of the plastic standard mortar,

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would have such advantages that the whole question would, by its means, be advanced a considerable step forwards, and it is very much to be wished that it may be tested in as great a number of testing establishments interested in Question No. 42 as possible. For my own part, I at once investigated it and conducted the operations in such a manner as to verify the following points in particular:

(a) In what degree does the volumetric weight of the fresh mortar depend upon the quantity of the mixing water and upon the amount of the ramming done, and what alteration results from these considerations for the strengths and for the degree of uniformity of the results?

(b) Do standard mortars with different quantities of water and different ramming, but the same volumetric weight, give the same test-results with a given cement?

(c) Is it possible to obtain standard mortars having the same previously fixed app. spec. gravity (2—17 or 2·25) with all sorts of cements, and is this app. spec. gravity in every case accompanied by an admissible consistency?

In order to test this programme, experiments were made with three cements differing largely in fineness of grinding.

1 Portland cement of medium fineness of grinding with residue of 27·5 per cent. on the 4900 mesh sieve;

1 Portland cement coarsely ground, in correspondence with the French booklet of requirements for marine structures (44·5 per cent. residue); and finally,

1 hydraulic lime of special manufacture, which on the same sieve leaves a residue of only 1½ per cent.

These mortars were in every case composed of 900 gr. of cement and 2,700 gr. of sand from Leucate, which had passed through the sieve with round holes of 1·5 mm. dia., and had been retained by the sieve with 1 mm. holes. It was worked for four minutes with the trowel with a variable quantity of fresh water, and the consistency was then estimated. A prismatic mould of 4 by 4 by 16 cm. was filled with material of the degree of density laid down for each experiment, the contents of the mould were weighed, and the 6 final prisms were produced, these having all undergone the same degree of ramming. The ramming was, as usual, performed by means of a small wooden dolly of 2 by 3 cm. in section with rounded corners, held by two fingers without the use of force. This is to be understood as ordinary ramming. Hard ramming was applied a few times, or on the other hand the mortar was pressed into the mould with the fingers. The prisms were removed from the mould after 24 hours and immersed in water, and they were tested 28 days after production. Before the test took place—*i.e.*, immediately after the removal of the water, they were gently dried on the surface and weighed separately, whereupon, after the pressing out of the water, their exact volume was determined by means of the Ludwig Volumometer. The app. spec. gravity of the mortar at the test is obtained as the quotient of weight by volume. The bending test was conducted exactly in accordance with the directions which Mr. Schüle had given in his programme. 100 gr. of shot was allowed to fall per second.

Compression Tests.—The compression tests were made by means of the Amsler-Laffon Press, with the two halves of the prisms that had been broken by bending placed crosswise between two steel plates 4 cm. in breadth.

TABLE I. **SERIES No. I OF TABLE II.**

No. of the Prism	Determination of the apparent sp. gr. of the Fracture (Prism)				Bending Tests		Compression Tests			
	Weight of the Prism	Vol. of the Prism	Apparent sp. gr.	Observations	Bending Strength	Difference from the General Mean	Strength of the Half-Prism		Difference from the General Mean	Mean Strength of a Prism
1	569·5	230·5	2·195		39·8	+ 1·2	201·5	204	+ 2·5 + 5	202·75
2	567·1	258·8	2·195		38·1	— 0·5	204	183·5	+ 5 —15·5	(193·75)
3	567·2	259·5	2·186	Minimum	(33·4)	— 5·2	170·5	212	—28·5 +13	(191·25)
4	568·8	259·3	2·194		(37·5)	— 1·1	198	199·5	— 1 + 0·5	198·75
5	567·7	258·0	2·197		38·7	+ 0·1	185·5	208	—13·5 + 9	196·75
6	576·6	262·3	2·198	Maximum	44·0	+ 5·4	214	207	+15 + 8	210·5
	General Mean		2·194	—	38·6	(2·25 = 5·8% of 38·6 (—	199·0		(0·7 = 49% of 199·0 (	—
	Mean of the 4 highest			—	40·1		—			202·2

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TABLE II.

No. of the Series	Quantity of Water in per cent.	Consistency of Mortar	Observations as to the Manner of Mixing and of the Ramming of the Mortar into the Mould	App. Spec. Gravity during Production	Apparent Spec. Gravity at the Test after 8 Days			Strengths per cm² (Mean of the 4 Highest Values)		Mean of the Deviations in per cent.	
					Min.	Max.	Mean	Compress.	Bending	Bending (6 Prisms)	Compress. (12 Half-Prisms)
FINELY-GROUND HYDRAULIC LIME (Residue = 1·5 Per Cent.).											
1	11	Good, rather stiff	Rammed in with the fingers	2·18	2·186	2·198	2·194	40·1	202·2	5·8	4·9
2	10	Too stiff	Ordinary ramming	2·28	2·201	2·220	2·212	44·3	233·7	4·6	3·1
3	11	Good, rather stiff	Ordinary ramming	2·30	2·248	2·263	2·254	51·0	269·4	3·4	2·3
4	12	Good	Ordinary ramming	2·26	2·202	2·220	2·207	44·0	220·1	3·2	3·0
5	13	Too soft	Ordinary ramming	2·20	2·148	2·158	2·154	37·2	150·2	3·5	2·0
PORTLAND CEMENT OF MEDIUM FINENESS (Residue = 27·5 Per Cent.).											
6	8	Too stiff	Ordinary ramming	2·18	2·209	2·225	2·216	29·3	127·3	4·5	3·3
7	9	Good	Ordinary ramming	2·20	2·204	2·211	2·208	34·6	146·4	7·6	4·8
8	9	Good, rather stiff *	Same assistant ordinary ramming	2·20	2·182	2·200	2·191	30·9	128·9	3·7	3·6
9	9	Good, rather stiff *	Ordinary ramming †	2·20	2·198	2·206	2·201	30·7	133·3	5·4	4·4
10	9·5	Good *	Ordinary ramming †	2·205	2·185	2·206	2·192	28·4	132·6	8·2	3·8
11	10	Good *	Rammed with fingers †	2·205	2·172	2·187	2·179	30·7	134·4	4·6	4·8
12	10	Good *	Ordinary ramming †	2·24	2·188	2·199	2·191	29·3	128·3	6·1	3·7
13	9	Good	Harder ramming	2·23	2·229	2·254	2·240	39·7	163·4	3·2	3·9
14	10	Good, rather soft	Ordinary ramming	2·18	2·168	2·184	2·177	32·0	123·6	4·4	4·8
15	11	Rather soft	Ordinary ramming	2·16	2·137	2·147	2·143	30·6	121·1	4·9	3·5
COARSELY-GROUND PORTLAND CEMENT (Residue = 44·5 Per Cent.).											
16	10	Good	Rammed with fingers	2·14	2·090	2·100	2·093	19·3	65·4	6·4	5·5
17	9	Rather stiff	Ordinary ramming	2·185	2·158	2·182	2·170	20·8	88·9	5·9	3·3
18	9	Rather stiff	Harder ramming	2·20	2·179	2·193	2·188	22·8	107·1	5·7	2·8
19	10	Good	Ordinary ramming	2·22	2·139	2·152	2·145	25·2	97·7	3·7	4·3
20	11	Rather soft	Ordinary ramming	2·18	2·132	2·138	2·135	22·8	79·5	5·8	3·6
					Mean of the 20 series :					5·0	3·6

* Produced 7 days later than series 6, 7, 13, 14, and 15.

† Another assistant (for this series only).

In order to determine the degree of agreement between the results given by each series of six prisms the means of the six bending strengths and of the twelve compression strengths were respectively computed; the differences between the individual strengths and these means were determined, and the means of these differences again, as functions of the mean strengths, were expressed in hundredths.

On the other hand, to enable the mean strengths to be compared one with another the mean of the four highest strengths of each series of six prisms was taken into account, in accordance with the programme of Mr. Schüle, after the mean of the strengths of each prism had been determined from the figures for the two halves for the pressure.

In general the smallest and greatest strengths in each series correspond with the smallest and largest volumetric weights. Exceptions, however, are of pretty frequent occurrence.

Table II. gives the circumstances of the production of the individual prisms, their consistency, the app. spec. gravity ascertained in the mixing process, and the mean results calculated in the manner explained above.

CONCLUSIONS FROM M. FREY'S FINDINGS.

The principal conclusions to be drawn from the above are :—

(a) The app. spec. gravity are not the same after 28 days as those at the production of the samples, although it may in both cases be assumed that the latter are saturated with water; they are generally somewhat smaller, but vary in the same sense. The determination of the app. spec. gravity of the mortar in process of being mixed appears to be less exact than that of the mortar when set.

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(b) With one and the same cement the app. spec. gravity of the mortar may vary within pretty wide limits according to the quantity of the mixing water used and to the degree of the ramming. With given ramming the app. spec. gravity rises at first with the quantity of water, reaches a maximum when the consistency is neither too stiff nor too thin, and falls again for larger quantities of water. The rule given by Mr. Frey, by which a given app. spec. gravity is obtained only in conjunction with an alteration in the quantity of the water, is applicable only to mortars which are produced in softer consistency than that corresponding with the maximum of the app. spec. gravity.

(c) The maximum of the app. spec. gravity of the mortars with equal ramming varies with the cement, and it appears difficult to establish a typical app. spec. gravity that corresponds with an admissible consistency with all possible cements. The mortar, 1, 14, 17, or 20, all of which in their fresh condition have a app. spec. gravity approximately equal to 2·18, might perhaps fulfil the condition. The proof, however, is wanting that all cements of this app. spec. gravity will give an admissible mortar, and further investigations in this direction would be necessary. Later experiments have shown me that the German standard sand gives a somewhat smaller app. spec. gravity than the sand from Leucate.

(d) The bending and compression strengths increase at a rate that is parallel with that of the increase of the app. spec. gravity. The proportion is also fairly regular, even when the app. spec. gravity of the set mortars are taken into account. An insight into these conditions is obtained by means of diagrams, when, for various mortars with a given cement, points are set off, which have the app. spec. gravity as abscissæ and the strengths as ordinates. When the unavoidable errors in the process of investigation are taken into account the strengths of the mortars with given app. spec. gravity with the same cement show large with differences when mixed with different quantities of water and different degrees of ramming.

(e) Even we had, at the outset, been able to believe that the thinnest mortars would be the easiest to ram, and that strengths would thus show themselves in each series which would agree better among themselves, the facts show that the relative deviations from the rule of the individual results for the various mortars, as computed from the means, vary in a quite irregular manner. The conclusion must here be drawn that, in one and the same laboratory and within the limits within which the experiments were made, the degree of agreement of the strengths obtained with the six prisms of each series is almost independent of the composition of the mortar.

Conclusion. – In conclusion Mr. Frey's method in its present form does not appear calculated to provide a solution of the double problem that was set for consideration, and fresh investigations would have to be undertaken in order to put the method on a more exact footing. It may, indeed, be questioned whether, with given ramming, the proportion of the mixing water cannot be set down as that corresponding with the maximum app. spec. gravity. It would, in every case, be desirable that each of the members of Committee No. 42 should make investigations of his own in order to discover the best solution of the problem, for the success of their work above all depends upon this.

We need not, it may be observed, be appalled at the rather considerable differences appearing under different conditions in the foregoing experiments between the strengths of the mortars, or be led to base arguments upon them against the adoption of the plastic mortars. The rammed mortars show differences that are no less considerable, when they are not produced under identically the same conditions, and we saw some years ago how comparative experiments in a number of German laboratories with rammed mortar made with the same cement, the same sand, and the same ramming apparatus gave greatly differing strengths.

THE SUBJECT GENERALLY.

Influence of Ramming. — In addition to the work of Mr. Feret, Mr. Petersen has carried out some experiments in the testing laboratory in Copenhagen on the method set forth in the President's circular, with the object of determining the influence of the ramming with 60, 80, and 100 strokes per minute. In his communication he mentions that it would be of interest to simplify the determination of the ramming of the mortar by laying down the rule that a rammer is not to be used, but that the mortar is to be pressed in by hand alone.

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Mr. Feret's Table II. shows that this method of production gives individual differences which are greater than in the other one.

Such being the state of the question it could not be of any use to distribute samples of the same cements among the different laboratories. The results would not be certain, since doubt still exists as to the best method of determining the quantity of water and the work of ramming. Mr. Frey had this problem investigated afresh in the laboratory of the cement works of which he is manager, and he was led to propose a new method for the production of the block samples, which after being discussed in Basle with Mr. Feret and the President of the Committee in October, 1908, was tested with a number of cements in the Federal Testing Laboratory in Zürich, and which is used as a check on the daily work of manufacture at Luterbach. The following arguments in establishment of this method are taken from a notice supplied by Director Frey:

The Quantity of Water.—On various occasions it was shown that the results of the prism-method become more regular when no water is allowed to trickle through at the lower part of the mould, and have accordingly tried to prevent this or to reduce the leak to a few drops. On the other hand, it was our endeavour to attain a constant app. spec. gravity, since the strength varied with the latter. The app. spec. gravity of the prism after its production is altered by its being kept immersed in water to the greater extent the more porous the mortar. The prisms, the increase of weight of which is abnormal, should accordingly be left out of account in the calculation of the results.

Now instead of the quantity of water being so regulated that the same ramming and always the same app. spec. gravity are attained, a certain quantity of water can be kept constant, and in each case the same weight, sand, cement, and water required for the exact filling of the 6 divisions of the mould may be made use of. The constant app. spec. gravity will then be attained under the condition that no water shall escape from the lower part of the mould. The ramming work will differ somewhat, according to the binding-medium used; but this presents no difficulty, if care only be taken that the mortar be made as plastic as possible by working. With Swiss standard sand we have chosen the proportion "11 per cent. of water," and the plasticity attained might seem to vary to a considerable degree with the cement. The experiments undertaken have shown that very different qualities of Portland cement may be worked up with this quantity of water without difficulty, and give the same app. spec. gravity for the prisms.

The employment of a constant quantity of water seems to be in opposition to the ordinary method, which seeks to attain the same degree of consistency by means of the variation of the quantity of water in the standard mortar. There are good reasons, however, for questioning the suitability of these variations. Indeed, since the sand is always the same, only the nature of the cement has an influence on the quantity of the water. A coarsely ground cement will usually require less water than a finely ground one, so that the strengths of the former will, in comparison with those of the latter, be the greater; on the other hand it would appear that there should be a simple proportion between the quantity of water which is used for the standard consistency in the setting test and that of the standard mortar of 1 : 3. This, however, is not the case, as may be seen when the standard quantities of water for the pure cement and for the standard mortar, respectively, are compared with one another. With Swiss Portland cement the former will vary between 34 and 23 per cent., and the latter between 9·5 and 10 per cent., and this in a quite irregular manner. For these reasons it would be an advantage to depart from the principle of the same consistency of the mortar, and, for the filling of the mould, in every case to make use of the same quantity of fresh mortar with a never varying proportion between cement, sand, and water.

It becomes necessary, then, to fix the quantity of the water in such a manner that it will be possible to fill the mould and ram the mortar without leakage occurring at the bottom. The proportion of 11 per cent., which was in general attained with Swiss standard sand on the application of the method set forth in the circular of the President, is found by experience to accord with the conditions above laid down.

The question of the quantity of the water with other standard sands then remains for solution. In the case of mortar of 1 : 3 with Swiss standard sand, the theoretical quantity of water necessary for the attainment of a compact mortar that exactly fills the hollow spaces in the sand is 9·5 per cent.—*i.e.*, 1·5 per cent. less than for the plastic mortar. For the German standard sand this calculation would give 10 per cent. of water in place of the 11 per cent. with the Swiss standard sand. In this respect further experiments are necessary.

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NEW TESTING METHOD FINALLY RECOMMENDED.

The new method would replace the one given in my first circular, and the points for the mixing of the mortar and the production of prisms would have to be altered in the following manner as based on the Frey proposal for the mixing of mortar and the production of prisms.

Mixing of the Mortar.—For the simultaneous production of six prisms:

2,340 gr.	German	standard	sand	780 gr.	cement	= 3,120 gr. or
2,280 ,,	Swiss	,,	,,	760 ,,	,,	= 3,040 ,, ,,
2,370 ,,	French	,,	,,	790 ,,	,,	= 3,160 ,,

are to be simultaneously mixed together in a shallow vessel dry, following which,

with	German	standard	sand,	10 per cent	=	312 gr. of water or
,,	Swiss	,,	,,	11 ,,	,,	= 334 ,, ,, ,, ,,
,,	French	,,	,,	10 ,,	,,	= 316 ,, ,, ,,

is to be poured on in two portions; the mortar is to be thoroughly worked till it is as plastic as it can be made.

Production of Prisms.—For one prism one-sixth of this mortar is weighed out and rammed into the mould, half at a time, with an iron pestle of 1 kg. in weight and of 3 by 3 cm. stamping-end surface. To begin with the mass of mortar is rammed only to such a degree that it goes into the mould and stands somewhat above it. Not till all the six divisions of the mould are thus filled is the ramming completed, care being thereby taken:

1. That, as a sign of complete binding, the slime formation on the tops of the individual prisms has taken place, and

2. That no water, or not more than a drop here and there, appear at the bottom of the mould on the completion of the ramming.

After being kept for 48 hours in moist air the mould is taken asunder, and the prisms are kept under water until just before the test.

The members of the Committee have been invited to examine these altered methods, and it is to be wished that at the next meeting of the Congress it may be possible to base the discussion upon completed experiments, so that a uniform method for the testing of cement may be arrived at.

It is scarcely probable that the hydraulic limes can be tested in the same manner; for it is, above all things, a uniform method for the testing of cements, and especially of Portland cements, that is required.

The conclusions which can at this stage be drawn by the reporter from the experiments made may be summarised in the following manner:

1. The testing of cements by means of prisms made from plastic mortar is distinguished by its extreme simplicity, and by the great advantage that both bending and compression tests can be obtained from the same block-samples. This testing process is the solution of the question as to equal capacity of the tensile and compression test samples.

2. The individual differences compared with the mean are smaller by this method than by the use of tensile test samples of 8 shape. For compression tests there is no considerable difference between the individual deviations and the mean values given by the results with cubes or with prisms

3. The smaller strength figures given by the prism method correspond better with the strengths which have to be dealt with in practice than do the high degrees of strength of mortar of earth-moist consistency subjected to hard ramming.

4. The difficulty of exactly determining the mixing-water and the work of ramming is solved in a satisfactory manner by the Frey proposal, which consists in the exact filling of the six divisions of the mould without the separation of water, so that with every cement the same weights of the latter, of the sand, and of the water are used, in order in this way to attain the same app. spec. gravity of the test samples with fresh mortar.

5. Finally, the testing method with prisms gives the compression tests the importance which they deserve, and which far exceeds that of the tensile and bending strengths, whether by reason of their regard to regularity or of their practical importance.

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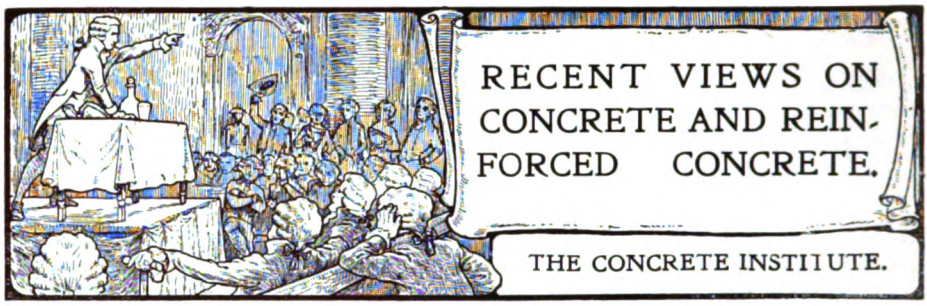

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.

The method we are adopting, of dividing the subjects into sections, is, we believe, a new departure.

THE opening meeting of the second session of the Concrete Institute was held at the Royal United Service Institution, Whitehall, S.W., and there was a large attendance of members and visitors.

The meeting was devoted to an impromptu address by Mr. Richard L. Humphrey, M.Am.Soc.C.E., of Philadelphia, who is one of the leading authorities in the United States on concrete and reinforced concrete. The address was an exceedingly interesting one, and was illustrated by lantern slides showing different examples of reinforced concrete work.

SOME POINTS RELATING TO CONCRETE AND REINFORCED CONCRETE IN THE UNITED STATES.

ADDRESS by RICHARD L. HUMPHREY, M.Am.Soc.C.E.

Secretary to the American Joint Committee on Concrete and Reinforced Concrete.

Mr. A. Ross, M.Inst.C.E., Chief Engineer, Great Northern Railway, presiding, in the unavoidable absence of Mr. Edwin O. Sachs, F.R.S. Ed., Chairman of the Executive, opened the proceedings by announcing that the membership of the Concrete Institute now numbered 855, with 17 special subscribers.

MR. RICHARD L. HUMPHREY, M.Am.Soc.C.E.

The lecturer began by stating that they had watched from the other side of the water the formation and development of the Concrete Institute with a great deal of interest, and hoped that great and good work would result from its formation. He understood it was primarily engaged in the work of education, and this to-day was the keynote in the development of the use of concrete.

He had visited many parts of the United States and Canada, inspecting the work going on there in reinforced concrete, and also in the principal cities of the Continent. After over 15 years' experience in concrete he felt in a measure qualified to speak on the subject, and would give some of his views as to the future possibilities of the material and the great needs at the present time in this field.

Generally. Concrete itself, as was well known, was an old material. It was used by the ancient Egyptians and Romans many years before the Christian era; and, while there exist structures thousands of years old, yet at the same time the Portland cement concrete we were using to-day was quite another material, superior in every way, and the reinforcement of it with steel had opened up a field which was apparently limitless. It was interesting to him to be here in England where so many important events had occurred in the history of the manufacture of cement. The names of Parker, Aspdin, John Grant, Ransome, and others need only be mentioned to bring before their minds important periods in the history of this great industry.

One had only to watch the development in the production of cement, of Portland cement, in the various countries to realise that the production must be hand in hand with the consumption, and that this ever-increasing production must mean an ever-increasing use. One of the things which had particularly impressed him in his visit to Europe was the fact that while there was a great deal of cement used in Europe there were not by any means the great variety of uses that would be found in America, which would be seen later on from the views to be shown, and which would, in a measure, show the many uses to which cement was being applied and the great field for the material.

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Standardisation of Methods.—It was perhaps a fact that in the development of the use of any material the standardisation of methods and other details of scientific importance must follow the use of that material. So it was with concrete. The use of the material had far outreached the scientific development of facts in connection with the subject, and the great need to-day was for a more intimate knowledge of such important matters as the allowable working stresses, the behaviour of this material under repeated loads, under static loads, whether the reinforcement should be placed in position as a unit or should be placed loose, whether there should be rigid connections between the reinforcing members of two adjacent beams or between a beam or a girder and a column ; the question of the durability of the material, of its ability to withstand corroding influences. There were a great many things in which there should be international co-operation, especially in this matter of standardisation of methods. The laboratories in America and similar institutions in Europe were carrying on investigations, for which the Governments were also furnishing funds. If we could crystallise into some definite form what is known in the various countries on the subject of concrete a great deal of useless work in fields that did not need investigation would be saved. Education was the great thing, the most needed thing, in development of the proper use of concrete. That so simple a matter as the proper mixture and the amount of water to be used in concrete was subject to such extreme interpretation in the various countries of Europe had astonished him. In parts of the Continent concrete was being used so dry that the repeated tamping of heavy tampers was just about sufficient to make the water come to the surface ; beams and slabs of rather large spans were being put in under those conditions, and it was astonishing that under such abuse concrete could do such good work.

The lecturer said in America they formerly believed in dry concrete, and then they went to the other extreme and used concrete so wet that the cement would separate from the aggregates, and which often resulted in a porous mass. Now they had come back to the neutral position, and it was the best practice to mix the concrete just as wet as was possible, and still of a consistency that would keep the cement and the aggregates in proper relation, and they found the best way to obtain this was by mixing, thorough mixing, before a material was placed in position, and yet he considered very little attention was generally given in Europe to so important a question as mixing.

Architects and Reinforced Concrete.—Another difficulty in the development in the use of concrete was in the education of the architect. There was no question that the great pieces of work with which the engineer had to do were massive structures in which the architectural features were of secondary importance to their strength and utility. In such structures concrete was being used to a large extent ; but in structures in which the architectural features were of prime importance concrete was not being used to the extent it should because the architect was not yet able to think in concrete. He had been trained in the use of such materials as brick, stone, steel and terra-cotta, and was therefore obliged now to think of a new material, a plastic material that did not always lend itself to the designs that he had used for those other materials. The architect had not yet wakened to the real value of this material, which had a great deal to do with throttling the development of the material, and yet concrete afforded one of the best materials to-day for the constructor.

If the architect could be brought to realise that he could take this plastic material and readily mould it into a structure of the requisite strength and durability, and which when completed would be homogeneous and monolithic, we would then be able to make some real progress.

One of the things which also impressed him was that in Europe there was a much more artistic treatment of concrete as a building material than in America. In Germany, Austria, Hungary, and other places there were very handsome ornate buildings in which concrete had been very simply treated, and yet with excellent artistic effect. He would return to America with the conviction that there was even a greater future for concrete than he had believed possible, and that there would be a much more rapid development here in Europe than they had experienced already in America.

Bridges.—The first use of concrete in America was largely in side-walk construction and in massive abutments, piers, and retaining walls. The early uses of cement were confined to these lines till 1893, when the first reinforced concrete bridge was built in America (in Philadelphia), with which he had been connected. We were now using concrete largely for bridges of all kinds, which in those days was used almost entirely in bridges for highway purposes, since it was not deemed advisable to build so important a structure as a railroad bridge of concrete, and many of the first bridges built were very massive, cumbersome affairs. Now the concrete bridge construction had developed so that they were cutting out a great deal of the massive materials in the spandrils, and bridges with open spandrils and of great beauty were being erected all over America.

The concrete bridges had developed rapidly in span and length, and there had just been completed the largest concrete arch bridge in the world, the history of which was extremely interesting. It was originally designed to be of stone, but the estimated cost of construction in stone was much greater than the money available for the purpose. It was then proposed to build the arch rings of stone and the remainder of concrete. But the estimated cost also exceeded the appropriation. Finally, the bridge was designed entirely of concrete, and had been erected at a cost less than the money appropriated for the purpose. But this would soon be excelled by another entirely of concrete, of which they

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were about to begin the construction in New York—the Hudson Memorial Bridge of 750 ft. span.

Another early application in the use of concrete in America was in connection with subways. It was first used in the Boston subways, afterwards in New York, Philadelphia, and other places, and it has proved to be a material which was peculiarly suited for these conditions. The permanency of the work, minimum maintenance charges, the character of the structure underground, where it was subject to dampness, all pointed to concrete as the material best suited for the purpose.

Railway Sleepers.—Another phase of the development in the use of concrete in connection with railroad work was for sleepers. The constantly increasing cost of wooden sleepers had led to the suggested use of concrete, but unfortunately the rigidity of the road-bed in which concrete sleepers was used, and the direct contact of the rail with the concrete had caused the sleepers to have a very short life under the repeated hammer of the passing locomotive, so that recently some of the sleepers had been made in which wooden plates had been inserted under the rail to cushion the sleeper and take up the shock, and there were on a number of railroads stretches of experimental track in which the sleepers were of concrete. The advantage of the concrete sleeper was the fact that the cost of maintenance was very much reduced and the alignment more easily maintained.

Concrete Pipes.—Another early use of cement in America had been in concrete sewers and cement pipes, and constantly increasing quantities were being used in the large cities such as New York, Brooklyn and Philadelphia. Plain cement pipes had been in use for 25 and 30 years. In Germany the engineer seemed to be afraid of the action of water on concrete, so it is almost the invariable practice all over the Continent, except in France, to use a vitrified clay lining, or a brick lining for the portion where the water came into contact with the sewer. In America they did not use a lining, except where the grades were very great, and in such cases a brick or stone lining was used to prevent the souring action.

In some parts of the country the alkaline soil, containing sulphate of lime, has been such as to cause a disintegration of the concrete, and in some cases of brick and stone also. They were carrying on research work in America in connection with their sea-water investigations to determine just what effect the alkalies had on concrete and other building materials, and also the methods to prevent this action.

Concrete in Earthquake Districts.—The efficient manner in which concrete withstood the stresses produced by the San Francisco earthquake proved it to be one of the materials best suited for that purpose. The line of faulting passed south of San Francisco along the Pilarcitos pipe line of the Spring Valley Water Company. He would show a view of one of the large dams of this company entirely of concrete, which was located about 100 ft. from the fault line, and while the whole country in the vicinity of this "fault" was shaken and affected by the earthquake, there was no evidence of any damage to this dam. The adhesive strength of concrete seemed to enable it to resist the stresses produced by earthquake action much better than masonry walls of stone or brick, and it had been greatly used on the Pacific coast and particularly in the reconstruction of San Francisco.

The use also of concrete for water tanks was becoming very general, and in many parts of the Continent the ornamental character of such tanks and towers, the thinness of the walls and the general economical design was far ahead of what they were doing in America.

Concrete for Docks.—Another interesting subject was the use of concrete for dry docks. The naval authorities had an idea that concrete would be affected by sea water. He had visited the sea-water laboratories of the Continent, and inspected reported cases of disintegration, and he believed that concrete, when properly made, of proper density, and allowed a fair time to set before it was subjected to the action of sea water, was perfectly safe. It was the porous, badly made concrete, improperly placed, that apparently was affected, especially at the water line, where it is subjected to the action of frost. He did not wish to convey the impression that concrete was not affected by sea water, for under favourable conditions such was the case. But he did wish to state that concrete properly made and placed was not seriously affected by sea water.

Concrete Piles.—Another application and development in America was the use of concrete piles. Piles had been driven there as long as 40 ft., and he had tested, personally, piles which had been driven and afterwards excavated; these piles had been driven by a hammer of 2,000 lb., and were not damaged in any way. Of course, there were a number of other types of piles. Some in which a steel shell was first driven, then the central core was withdrawn and the shell filled with concrete. Some were formed by driving a heavy metal shell and filling in concrete as it was withdrawn. The former must be tight, otherwise in sea water there would be a dangerous corrosion.

Concrete Fences.—Another development in America was the use of the concrete post for fencing purposes. Farmers were beginning to find that, while the first cost of the posts was somewhat greater than wood, they could use them to great advantage. They kept the fence in better alignment, the cost of maintenance was less, and especially in those great plains where they had fires in the autumn. Railroad companies found that along their right of way this was a very cheap economical way of fencing, because the fires which were occasioned by the sparks from the locomotive had no effect on a concrete post.

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Concrete on the Farm.—The most interesting application of concrete in America was in connection with the farm. It was the small user, the man who used 10, 15, or 20 barrels a year, which, when aggregated, made the enormous consumption which took place. Great quantities of cement were used in the construction of side walks annually. Every city and every little town and hamlet must have its concrete side walk, and so in America every farmer must have concrete in some form; he found it a great advantage to use concrete in the construction of his spring houses, where he keeps his butter and milk, and he used it in his silos, where he stored his corn and grain. It was the material used in the buildings constructed by the farmer, and there were many pamphlets being issued by the various organisations which told him how to do it. It was used in the buildings for dairies; they had in America a great many scientific dairies where everything was done with the idea of keeping the milk perfectly clean and sanitary, and concrete was almost exclusively used in the construction of the buildings. The farmer was using it in his barn, especially in the West. Again, in feeding his stock, he found it a much greater advantage to use a concrete feeding floor, because the feed was not trampled into the mud and dirt by his stock. All through the west there were constantly increasing cases of concrete being used in the construction of the barn, farmhouse, silos, for fencing, and for other purposes, and many of these buildings were assuming quite artistic shapes and were attractive objects in the landscape.

Warehouses and Stores.—Another important use of concrete was in the construction of warehouses, factories, stores, and shops. Heretofore, it had been the practice to build these structures, especially in the city, with walls of brick, as is also the practice in Europe, where the walls were brick and plastered with cement mortar. But the architects were now beginning to use concrete for the walls, and they found the effect very good. A great many of the factory buildings in America were constructed of wood, and known as "mill construction"—that is, slow-burning construction. The cost of that construction roughly was about 10 cents per cu. ft. As the price of lumber increased, as it became scarce, concrete began to be used for the purpose, and to-day, while the price of the wooden "mill construction" was upwards of 10 cents a cu. ft., the concrete structure could replace it for about 10 cents and less; in some cases 8 cents per cu. ft. And in addition to that, the rate of insurance placed on it was so low that most of the manufacturers now used this in preference to other material.

Concrete for Cold Storage.—Another line in which concrete was being used was in connection with cold storage warehouses. Concrete was an admirable material for this purpose, because of the low rate of heat conductivity.

Reinforced Concrete Chimneys.—The use of reinforced concrete for chimneys and stacks had been very interesting. There had been cases where the stacks had collapsed, one particularly at Louisville, Kentucky. An investigation seemed to show that the chimney had actually swayed under the action of the wind, and the repeated movement of the chimney had caused the wearing away of the concrete at the joints. In America most of the chimneys were constructed with a fairly dry mortar or concrete. They usually placed about 5 ft. a day, and raised the chimney successively by rings of 5 ft., and the result was that the chimney oscillating in the wind had a tendency to rock at the joints with injurious effects. Where the chimney was made of fairly wet concrete such danger had not occurred, although in the construction of the chimney of the Butte and Montana Copper Company at Butte, Montana, 506 ft. high, lime mortar and hollow bricks were used. The theory of the engineer who designed it was that it was wholly improper to design the chimney solid, that if he had put in Portland cement in the joints, the chances were that the stack would have swayed with the wind and would have cracked; he wanted the stack to move slightly under the action of the wind, and he wanted elasticity; lime mortar joints were put in so as to take up the movement and prevent dangerous cracking. The difficulty, of course, in constructing a chimney of great height as a monolith was very great, and in the chimney shown they would see quite clearly the bands or rings which result from the day's work with the dry mixture. The advantage of the concrete stacks was that they did not have to be taken care of as in the case of a metal stack.

Reinforced Concrete Roofs.—There had been an interesting development in the use of reinforced concrete for roofs. The early experience was that the concrete in large areas would crack and the roofs would leak, and it was necessary, therefore, to put on some material, asphalt or some other material, to make them tight. There were now many buildings having reinforced concrete roofs that were watertight.

Of course, we all know that concrete was used as the base of a street with some wearing surface, such as wood, brick, stone, or other material, but he had seen a street in Europe made entirely of concrete, with wearing surface of concrete.

Concrete Houses.—The use of concrete in the construction of the home was another matter in which there had been considerable progress. There was some attractiveness about concrete apparently for the average person, so that quite a great many small concrete buildings were being erected in America. Perhaps additional impetus had been given to it by the fact that Mr. Edison, of electrical fame, proposed to "pour" a concrete house. He had not poured the house yet, and they were all waiting to see him do it.

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But it was a fact that they were building concrete houses in America, and some of them were really attractive. The cost of construction of those houses was also quite reasonable; in fact, in some parts of the country they were putting up groups of houses on the community plan, where they were heated, lighted, etc., from a central plant, and the effect was in many cases quite good. The use of the cement hollow block, which had been the *bête noire* of most people interested in this method of building in America, had developed quite rapidly, and now block houses were beginning to assume the appearance of something more than the name implied. Many of the attempts to use monolithic concrete by architects had also been successful.

Concrete for Ornamental Purposes.—There were a great many of the country homes in the vicinity of New York, Boston, and other cities in which concrete was being largely or entirely used for building, and the use of artificial stone had developed to quite a considerable degree in Boston. At Harvard College there were two buildings, one of granite, the other of artificial granite, and it was difficult without previous knowledge to tell which was the natural granite and which the artificial.

One of the things he had learned in his trip abroad was that concrete took a very good polish, a polish as good as marble, which he had seen demonstrated, and because of this fact there was a great future for concrete as an artificial building stone for ornamental purposes. The general effect of concrete in a landscape was good, and many of the gardens in New York and Boston showed the effect of the artistic use of concrete for these purposes. The use, however, of concrete for ornamental purposes, through the insertion of tiles of different colours, had great possibilities.

One of the novel developments in America was the erection of buildings on the plan of which he would show views. There was a frame, pivoted so as to balance properly, resting on hydraulic jacks on one of the outer ends. On this frame the door frames and window frames were placed, and then the reinforcement, finally the concrete, and finally the finish of the surface, the upper surface being the outer surface of the building. After the concrete had set, the walls, by the means of these jacks, were raised into a vertical position; after the four walls were so raised, the concrete beams, girders, and columns previously moulded were placed, and then they put the corner forms in and poured concrete into them, and after it had set you had a complete building. The advantage, of course, was that the cost of forms had been reduced to a minimum.

Concrete for Fire Resistance.—He wanted them to see views of a concrete building, the photograph of which was taken during a fire. The entire contents were destroyed—including the doors and windows—the building was afterwards cleaned of what remained, and new floors, doors, and windows put in; the walls of the building, being of concrete, were undamaged. There was another building which passed through the Baltimore fire. The walls were all brick, the front of the building of cast-iron. The only thing which remained in place and apparently in fairly good condition, considering the terrible treatment it had received, was the reinforced concrete.

He had been particularly studying in his trip abroad the building regulations and the losses of property by fire. They had found in America from statistics that the losses of property by fire were 3 dollars per person. The American Consular Authorities had collected statistics for Europe, and found that the losses were about 33 cents per person, or about one-tenth. So the question of fire losses and the prevention of fires was a serious problem, and there was no doubt that concrete was going to play a very important *rôle* in America and in Europe in this question of fire.

Various Investigations.—They had been studying the question of the permeability of concrete. In the porous mixtures the water went through very rapidly, but with the wet mixture the 1-in. section was sufficient to resist the pressure of water even at 60 lb. and 80 lb. In other words, if they properly proportioned and mixed the material they could get density to prevent water penetration. They would find this is true for only a small area; in large masses they must resort to reinforcement so as not to have cracks in which leakage could occur.

Another question they had been studying was, whether or not concrete could be artificially aged or its strength developed in a very short period through the use of steam, either at low or high pressure, and they had obtained some very interesting results. They had also been making an investigation of the beams and columns of reinforced concrete. In addition to that they had been carrying on some interesting tests of slabs of concrete. There were many other tests of the constituents of concrete, of methods of waterproofing and waterproofing compounds, effect of sea water and alkalies on concrete, etc.

In one of the phases of the fire test which they had been making, panels of various materials had been made and placed in the furnace, and one face of the panel submitted to a temperature of 1,700 degrees for two hours and then immediately quenched with water, and the effect had been very interesting as showing the conditions, particularly for concrete, that will best stand fire. The study of natural building stones had been equally interesting. It had been found that the hard way, the grain and the rift of the stone had a very important bearing on its ability to withstand the action of high temperatures.

In conclusion the lecturer pointed out the importance of co-ordination of the work in standardisation. He had been associated with committees in America for many years in efforts to standardise

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methods of testing and specifications, and he felt there was no reason why there should be among the countries of the world any greater differences in methods or specifiactions than there should be in a single country. They should have the same standards for testing cement as for steel and other materials, and they could if they would all try and adapt methods, after comparative tests which were suitable for the purpose. The great work that had to be done was the work of standardisation and the interchange of the views of the various countries. He hoped England and America would exchange views to co-ordinate their work, so that the work of standardisation among the English-speaking people at least might be as a unit, and much would then be accomplished that would be of value.

There was a great deal of work to be done in standardising methods of design and construction, in establishing proper working stresses, and testing the value of the various theories. The continued successful development in the use of reinforced concrete construction would in a large measure depend on how well and how quickly they carried on this work of standardisation. The most potent factor in this success would be the education not only of the technical man but particularly the artisan, the man who physically manipulates the material.

In this work the Concrete Institute could render invaluable assistance, and he hoped it would take an active part to the end that the use of concrete might be developed on intelligent and rational lines.

It had been a great pleasure to him to have the opportunity of addressing them, and he hoped he had offered some suggestions of value.

The Chairman then asked those who desired to participate in the discussion to do so.

MR. CHARLES F. MARSH, M.Inst.C.E.

Consistency of Concrete.—Mr. Humphrey pointed out the manner in which concrete formerly was mixed very dry on the Continent of Europe, and how it was gradually becoming the custom to mix it more wet. He was glad to say that he had always held the opinion that concrete ought to be mixed neither too dry nor too wet.

Size of Buildings.—There was one very notable thing in the slides which they had seen, and that was the magnitude of some of the works which had been carried out in America. He hoped that in the future they would have some very good types of construction in reinforced concrete in this country. Of course, in England they were not allowed, or very seldom allowed, to use outside walls in reinforced concrete. The new London Building Act he hoped would allow them to use those walls and then perhaps the architect might have his chance to show what he could do with this material in the form of mouldings.

Cost.—Mr. Humphrey mentioned the lowness of the cost of reinforced concrete buildings, and mentioned that some were as low as 10 cents, or about 5d., and they had been constructed at a cost as low as 8 cents, or 4d. A building of quite a plain character was about to be erected for the Metropolitan Water Board, in which, although the outside walls were not of reinforced concrete, only the floors, columns, and stairways being constructed of this material, the price had come out at about 4½d. per cu. ft., which appeared to be extremely cheap.

Mr. Humphrey also mentioned the fact that an engineer in the United States had built a brick chimney in lime mortar, and apparently it was rather an unusual thing to use lime mortar for the joints. In this country it was the general custom to use lime for the mortar for chimney construction.

Temperature Cracks.—Perhaps the worst feature of concrete construction was the cracks that were formed due to temperature and other causes—mostly temperature. The effect of these cracks on structures which had to resist the pressure of water was a very important one, and it was a subject which required a considerable amount of inquiry as to whether, even if the concrete in the laboratory did resist the pressure of water, in actual work structures which had any considerable head of water on them would resist the passage of water. There was a considerable danger not only from the cracks forming from the difference of temperature but also from the possibility of some few bad mixings being put into the work, and, of course, the weakness would soon be found out when the water pressure came on the structure.

MR. LUCIEN SERRAILLIER.

Mr. Humphrey had shown a view of some sleepers. Would he tell them why the sleepers were placed so near together ?

Mr. Humphrey: The placing of the sleepers was not any nearer than is the practice in America, but if anything the concrete sleepers were generally placed a little further apart than wooden sleepers. Probably it was the foreshortening effect of the photograph which gave the impression that those sleepers were nearer than they really were.

MR. J. WAGER (H.M. Office of Works).

He was afraid he was not very competent to speak on the subject of the lecture. He was an architect, and was rather forced into the use of reinforced concrete against his inclination. He was very interested in what Mr Humphrey said about the incompetence of architects in dealing with reinforced concrete, and he would study what he could do with reinforced concrete and the ordinary building materials combined.

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MR. H. W. TAYLOR, A.M.Inst.C.E.

Would like to ask the lecturer whether the dam which was shown upon the screen, and which so successfully resisted the San Francisco earthquake, was reinforced or plain? Also whether there were any other instances of curved dams constructed of reinforced concrete wholly? There were many curved dams which had been constructed of masonry and mass concrete, but were there any which had been constructed wholly of reinforced concrete, which would consequently be of a thinner form?

Mr. Humphrey: The dam mentioned was built of mass concrete and was not reinforced. The blocks were dovetailed in, and one block of concrete would be cast, and then another, so as to leave a space between the two blocks, which would finally be filled in, so that those masses of concrete dovetailed in together. Another instance of the curved dam was in the Shohone Canyon, in connection with the reclamation service work. The dam was one of the highest in the United States. The walls of the canyon, which were quite steep, were of red granite, and this stone was being quarried and crushed, and used in the dam made of concrete (not reinforced).

MR. W. H. JOHNSON, B.Sc.

Cracks in Outside Walls.—Had Mr. Humphrey found that reinforced concrete outside walls had suffered from cracks, say, rather more than a year after they had been erected?

Mr. Humphrey: It had been his practice to inspect a great many buildings after they had been erected a long time. He had charge of the erection of one building which was built entirely of monolithic concrete with thin walls, and it was a fact that it did crack; but that building was erected several years ago, when the knowledge of the proper methods of reinforcing walls of concrete to resist cracks was not so great as it is to-day. They had entertained the view in America that it was necessary in long masonry walls of concrete to have expansion joints; but recent experience had shown conclusively that this was not necessary. All that was necessary was to put in reinforcement, not only to carry the loads for which it was designed, but reinforcement for taking care of the expansion and contraction of the concrete, due to temperature changes and other similar causes. A number of long retaining walls and walls of buildings had been constructed in America reinforced in that way.

He had inspected bridges that were built in the early days—that is, since 1893. Those bridges were of mass concrete, and it was the practice to lay the concrete in horizontal layers of nine or ten inches. Going back to those bridges after an interval of eleven or twelve years, it was noticeable that there had been cracks developed right along—that is, the line of demarcation between the consecutive days' work had developed, and the water had come through, bringing out the salts of lime on the surface. As a result of that experience, in many places now in America they resorted to horizontal lines, and carried the work up successively by layers of nine or ten inches, but put the horizontal groined joint in so that a crack occurring there would not be visible.

MR. F. W. MARTIN.

Condensations.—How had they got over the difficulty of condensation on the condensed concrete of a house? Did they use hollow walls?

Mr. Humphrey: That was one of the problems of a masonry wall. The condensation of the moisture in the room against the cold surface was a thing that occurred, and it was overcome through insulating the wall in some way. With hollow walls, it seemed necessary to insulate the wall in order to get satisfactory results. There were several instances where houses had been built with rather heavy masonry walls of 10 or 12 in. thick which did not seem to suffer from the dampness, but the condition in concrete was no different from that in a stone house. The condensation which occurred in a stone house was simply due to the fact that the stone was colder than the warm air-carrying moisture which came in contact with it, and there resulted condensation.

Mr. Martin: In a stone house there was a brick lining to reduce the cold of the stones.

Mr. Humphrey: This had been tried in a number of cases, in basements particularly, where they had placed asphalt or some material of that kind against the concrete, and then faced with bricks; but in ordinary buildings the walls were generally very thin, and there was usually some furring on the inside so far as ornamentation went, though in Vienna and Budapest there were buildings which were finished on the concrete wall without any other treatment than plaster of Paris, apparently without any evidence of dampness.

MR. J. FALDER BURN

Regarding hollow walls, at Harrogate, in Yorkshire, they were quite dry.

MR. F. E. WENTWORTH-SHEILDS, M.Inst.C.E.

Railway Sleepers.—Mr. Humphrey had covered an enormous amount of most interesting ground. It would be useful, perhaps, to have a little more information about reinforced concrete railroad sleepers. He understood from Mr. Humphrey that a good deal had been done in that way in America. He thought that very little had been done in England or on the Continent, although he had read that a large number of experiments were being made on the use of reinforced concrete sleepers in Italy. But what little had been done in England had not been altogether encouraging, because the concrete had shattered—not the steel, of course, but the concrete itself—under the immense vibration produced by the heavy locomotives going over the rails. He understood Mr. Humphrey to say

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that in America they had introduced a wooden cushion with a view to decreasing the effect of that vibration. He would like to know if this device had been successful.

Reinforced Concrete for Cold Storage.—Reinforced concrete had been successfully used in England, as in America, for cold storage. When first adopted for this purpose it was hoped that the concrete would itself be an insulating material which would prevent outside heat from penetrating into the cold rooms. These hopes were somewhat disappointed, and at Southampton, where they had a large cold store, they found that it became necessary to provide inside the shell of the building a further insulation of timber and sawdust in order to keep the rooms at a low temperature.

Chimneys.—It was particularly interesting to hear that concrete chimneys, unless reinforced, were too rigid, and that the chimney tended to rock on its horizontal joints. A little while ago he had occasion to erect a chimney, about 150 ft. high, in the south of England. It was a brick chimney, but he was very anxious to reinforce it in some way to prevent the vertical cracks which so often occurred in large chimneys, and which were the cause of much anxiety to the engineer in charge of them. He thought that the right way to do this would be to bury the steel rods inside the brickwork. But everybody said: "If you attempt to bury steel rods inside lime brickwork, the result will be disastrous. The lime will have the effect of corroding the steel rods, and instead of protecting your building the corrosion will cause the joints to lift, and will break up your chimney automatically." On the other hand, he did not wish to build the chimney in Portland cement mortar, for fear of the excessive rigidity which Mr. Humphrey spoke of, so he constructed the chimney in lime mortar and introduced steel rods at intervals of about 4 ft.; but where the rods occurred, instead of laying the brickwork in lime mortar, he buried the rods in cement mortar, thus introducing a cement joint at intervals of 4 ft. That chimney was built about five years ago, and the result had been entirely successful so far.

He would like to ask Mr. Humphrey what was considered to be the best covering to put on to a flat reinforced concrete roof when the inevitable cracks occur, and when in consequence the rain got in.

MR. E. FIANDER ETCHELLS, M.F.Phys.Soc.

Standardisation of Symbols.—Mr. Humphrey was to be their envoy in the attempt to bring about a co-ordination in the standards and symbols between this country and America. Certain proposals had been put forward in the *Transactions*. They were not adopted at Copenhagen because they caused too much upsetting of the Continental systems, and it was rather hopeless to expect the general mass of Britishers and Americans to adopt the Continental system. It would have meant too much memory work, so that now our only hope was for an *entente* with the States, and Mr. Humphrey, he believed, would do his best to bring that about. Then, when the *entente* was accomplished, the differences in the formulæ would be essential differences rather than mere superficial differences of form and dress.

He would also be glad if Mr. Humphrey would assure the American Joint Committee that this Institute—composed as it was of engineers, architects, contractors, surveyors, and chemists, and comprising members of all the other institutions—was engaged on similar work to their own—*i.e.*, in consolidating opinion throughout the country. That is what they wanted more than anything else at present; for while they were as isolated units, the cutting of prices, and the undercutting that went on might lead to dangerous practices in design, and this, of course, would discredit the whole industry, although it might only be brought about by one or two individuals.

The doctrine of the lowest tender had much to answer for. With regard to the statement that the Americans burned up every year as much as they built, this must lead to an annual town planning, surely the *ne plus ultra* of town planning. He would like to know whether rusting had taken place inside some of the buildings; but, perhaps, America was not in a position to answer that question, because they apparently pulled their buildings down before the rust had had a chance to do its work.

He would like to hear Mr. Humphrey's opinion of the merits of bench work *versus* work moulded *in situ*—by "bench work" he meant the beam which was cast, say, out in the country and brought on to the site. Did Mr. Humphreys consider such a beam stronger than a beam moulded in position?

MR. H. K. G. BAMBER, F.C.S.

Cement and Sea-Water.—Amongst the many interesting points which Mr. Humphrey touched upon lightly, he was pleased to hear his opinion upon his own experience in America, and by reason of the experience he had recently had during his travels in Europe of the action of sea-water upon Portland cement; also that he had come to the conclusion that in most of the cases where trouble had taken place it had been due to the faulty construction of the work rather than to any particular action of the sea-water upon the cement itself.

Rusting of Iron.—Mr. Humphrey had also touched upon the question of the rusting of iron. That was again a very interesting matter, and it had been his privilege recently to inspect in Germany two or three instances of reinforced concrete construction which had been in existence for some 30 years or more, and he was pleased to find that, although those constructions were in a very exposed position in many respects, and the reinforcement was in some cases not more than half an inch from the surface, there appeared to be absolutely no sign of rusting of the enclosed iron.

He had with him to-night a piece of a drill, which had been taken from a piece of sea wall in Barbadoes. This sea wall was constructed more than 39 years ago, and at the time of construction

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the drill was forgotten, and became embedded in the concrete. Recently, when alterations were required, and the concrete had to be cut away, this drill was discovered, and the perfect state of preservation in which it was found was considered to be so interesting that it had been sent over here for the information of those who were investigating the question of the rusting of steel in concrete. The piece of drill would convince any gentleman who would care to see it that, after 40 years in concrete, in a case where the work has been subject to the action of sea water, there had been absolutely no deterioration of the steel which was accidentally embedded. For this interesting example he was indebted to Mr. Bowen, of the Public Works Department, Barbadoes, and to Mr. Parkinson, of Westminster.

MAJOR HARVEY.

Would Mr. Humphrey tell them whether the building they saw constructed on the site and then hoisted into position was really a commercial undertaking or an experiment to see whether such a thing were possible ?

MR. HUMPHREY.

Concrete Sleepers.—As to concrete sleepers, they had considerable experience in America, and most of their large railroads had been experimenting more or less with them. He had also investigated a great many concrete sleepers, and he had studied the new types as they had come out. The earlier type was one in which the rail was attached directly to the concrete with very bad effects.

The reason that the railroads are trying to obtain a satisfactory concrete sleeper was simply because of the increasing scarcity of good wooden sleepers they must turn to concrete for relief. Recently they had been creosoting wooden sleepers, and some of the softer woods were now being used that heretofore had been considered unsuitable. If a concrete sleeper could be made which (though its first cost might be much greater than one of wood) would last longer than a wooden sleeper, or at least as long, it was of course desirable. Some of these concrete sleepers had shattered in one or two years' service, while similar sleepers made at the same time lasted for one or two years without apparent damage, and were still good. In every case where he had investigated, and by conversation and inspection with the road foreman, he had found that, generally speaking, the cost of maintenance where the concrete sleeper had been used had been less, and the alignment of the track had been more easily maintained than with the wooden sleeper.

Another objection had been raised to the concrete sleeper by the motive power men. They contended that the concrete sleeper produced an inelastic track that was very hard on the engine. They did not have balanced locomotives in America, and, of course, there must be a certain elasticity in the roadway, and the rigid road-bed had produced rather bad effects on the engine itself. There had been a number of sleepers placed on the market in which a hardwood block had been placed directly under the rail, apparently with much better results. The sleeper seemed to have some of the resilience that is necessary to enable it to take the shock of a passing locomotive.

Concrete for Cold Storage.—Perhaps in the hurried way in which he touched on the subject he created an impression that concrete was used for cold storage purposes under conditions that did not require insulation. In every case where they had used concrete for cold storage purposes they had used insulating material—cork, sometimes sawdust, and other material. Concrete, being a poor conductor of heat, offered a material suitable for the walls, floors, and columns, and made a structure, as a whole, that was peculiarly adapted, with the necessary insulation, for cold storage purposes.

Coverings on Roofs.—As to the covering on roofs of reinforced concrete, of course that was a problem, and it was a common practice in America in most cases to resort to the use of tar paper, which they also used in this country—that is, gravel roofs composed of several layers of tarred paper covered with gravel or other similar material. In some cases tar had been used for painting the surface of the concrete, but that was of little value if the roof had cracked. Of course, the only way they could make it tight was to cover it with something elastic under expansion and contraction. Paraffin had been resorted to, but that was only a temporary expedient where the roof had cracked. Where the roof had developed cracks from the expansion and contraction they would have leakage unless the material they covered it with was elastic. On the other hand, if the roof was properly designed, with the necessary amount of metal, it would be tight and need no further treatment.

Rusting of Steel. The corrosion of steel embedded in concrete was a matter of great interest, not only in reinforced concrete, but also in a great many other structures ; for instance, the sky-scrapers in America, where structural skeletons of steel were embedded in concrete, terra-cotta, brick, or some other material.

He quite agreed with Mr. Bamber's proposition that with properly encased metal in concrete there was no danger of corrosion. Rusting could not occur without first an acid of some kind, as, for example, carbonic acid, to act on the metal and oxygen to oxidise or rust the material. If it was sealed from the air by embedding in concrete, which was basic and had an affinity for carbonic acid, no rusting could occur, even though the metal be rusted when it first went in. There might be a certain amount of rusting after the metal was in place, but the rusting could not continue unless a crack occurred which gave a line of communication from the air to the metal, which would

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permit the moisture to convey carbonic acid to the metal. Where the structure was properly designed there was no danger. In America he had inspected cases where the reinforcing metal had come within perhaps ¼ in. of the surface, and the corrosion and rusting of the metal had been sufficient to progressively lift the concrete from the face of the wall. So it was a fact that corrosion could occur under favourable conditions. Besides, there were certain aggregates used, particularly in the United States, which were a source of trouble. There were certain lime stones which contain sulphides, which oxidise and provoke rust. Another condition which might cause corrosion was where the reinforcement was exposed, either accidentally or otherwise. This reinforcement might then be the means for conveying rust into the interior.

Cement and Sea Water.—The action of sea water on the cement or concrete could be demonstrated by a simple experiment. On placing concrete or cement in sea water a white precipitate formed on the surface, showing there was some action on the cement. In the experiments in Atlantic City, where they had taken cements in powdered form and rotated them with salt water, and analysed the water, they had shown that there had been a progressive interchange between the cement and the sea water. The lime had gone into solution with the sea water, and the magnesia salts had gone out of the sea water itself. The condition that Mr. Bamber referred to, where the concrete was deposited in place, was very favourable to action of that kind. Concrete could be used in sea water successfully; in fact, he inspected some concrete walls in Copenhagen made with some of the first cement made in Europe. They had been there since 1852, and they were in an excellent state of preservation. Generally speaking, where the concrete was properly proportioned, mixed, and placed there was no danger. In a great many cases the damage occurred at the water-line, from the water freezing, especially brackish water, which injured the porous, badly-made concrete.

Beams and Columns.—An interesting question was raised by one of the speakers—namely, the use of beams and columns which had been moulded in yards and carried to the site and erected. This method had been tried in America, and the results had been a rather mediocre success, due to the fact that the method had not been sufficiently tested.

Manufacture of Cement.—Mr. Bamber also touched on the manufacture of cement. He did not have the courage to do that, because he realised that was a subject which would take a whole evening; so he very carefully avoided it, realising that the Portland cement made to-day was one of the best materials that had been made in the history of the world. Generally, the cement had to bear the burdens resulting from the bad judgment, lack of skill, and the ignorance of men who used it; the cement generally was amply good for the work. Besides, it was so hedged round now by specifications and requirements, which compelled the manufacturer to make a pretty good material, that it really had become a secondary consideration in a problem of this kind.

The last speaker asked about the walls of the buildings cast horizontally and then hoisted into position. The cases referred to were where the walls were moulded on movable platforms and then placed in position. That was being done commercially. There was a company formed, and two buildings were being built for the Army barracks, and a number of houses were being erected in Chicago by this method. He should have added in connection with that that under this system of construction, after the first wall was put up and the floor placed in position, these forms were raised to the second floor and the next floor was erected, and so it is claimed by the patentee there was no limit to the height you can go. (Applause.)

MR. E. P. WELLS, J.P.

They had all been very pleased to hear Mr. Humphrey to-night, and before he left a hearty vote of thanks should be passed for his most interesting lecture, and he hoped that at some future period they would have another address from Mr. Humphrey in London. (Applause.)

MR. W. G. KIRKALDY, Assoc.M.Inst.C.E.

It would be the feeling of the meeting to-night that a very hearty vote of thanks be passed to Mr. Humphrey for his admirable address. They were greatly indebted to Mr. Humphrey not only for his address, but for his remarks in reply to the questions asked in the discussion. That had been the most interesting and instructive part: he had handled the thing in such a masterly way, he was personally acquainted with so many of these problems, that it had been a great pleasure to hear him.

As to the thickness of the skin of concrete outside walls, they were very glad to hear Mr. Humphrey's views on that point. In the course of time information must be obtained to know where the danger zone would come. If the outside coating of concrete were made too thin, trouble might legitimately be expected; but they did not want to err on the other side by making the outside section too thick. He had great pleasure in seconding the proposal that had already been made.

THE CHAIRMAN.

Before putting the motion he wished to say that they had had an exceedingly useful and instructive evening, and he put it to the members to pass the vote of thanks to Mr. Humphrey by acclamation. (Loud applause.)

The meeting then terminated.

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NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

REINFORCED CONCRETE MILL AT BATTERSEA.

THE new Plumbago Mill which has been recently erected at Battersea for the Morgan Crucible Co., Ltd., is another example of the practical and economical use of reinforced concrete, and a case where the monolithic character of this form of construction is of particular value.

The building was designed and constructed throughout by the Empire Stone Co., Ltd., of Thanet House, Strand, W.C. The reinforcement consisted of Patent Indented Steel Bars.

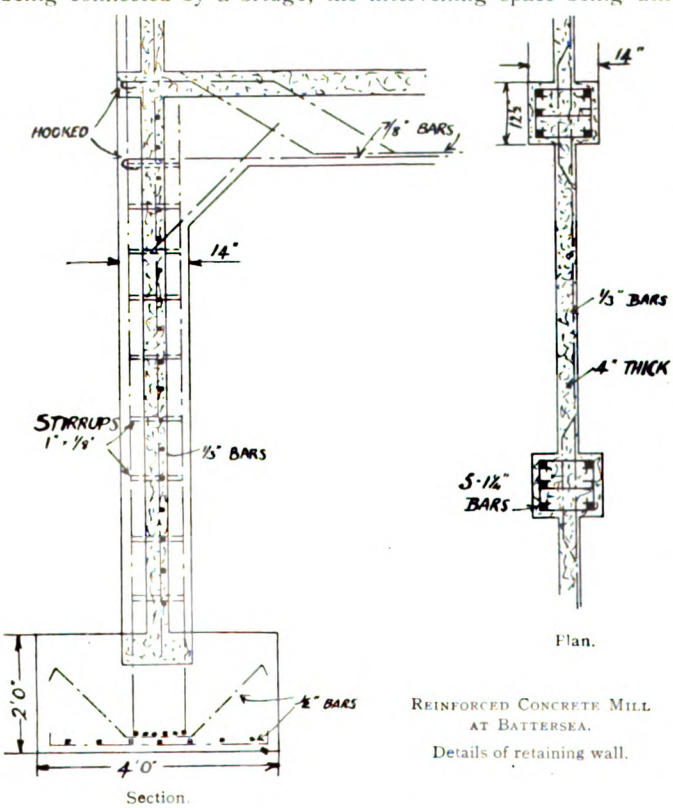
We are, in this case, only showing sketch plans, as there is much in the precise details of the lay out of this particular mill that the owners would probably prefer to keep private, but these sketch plans suffice to indicate all that is of importance to those interested in reinforced concrete construction, and they show very clearly how practical this method of construction is to this particular class of structure.

The building comprises premises covering an area of about 80 ft. by 80 ft., the height being approximately 50 ft. It is laid out in two blocks of bins, these blocks being connected by a bridge, the intervening space being utilised for the installation of crushing machinery which is supported on reinforced concrete foundations. The total area is covered by a flat roof of reinforced concrete, into which skylights have been introduced.

The sketch plan on page 507 shows that there are 44 bins 5 ft. 10 in. sq. in one block, and 84 bins 2 ft. 10 in. sq. in the other. The walls of these bins are only 4 in. and 3 in. thick respectively.

There are also 15 special packing bins, sketch details of which we show on page 508.

The whole of the bins are constructed with hoppered bottoms, the outlet being 8 in. in diameter, and these bins are used for



REINFORCED CONCRETE MILL AT BATTERSEA.
Details of retaining wall.

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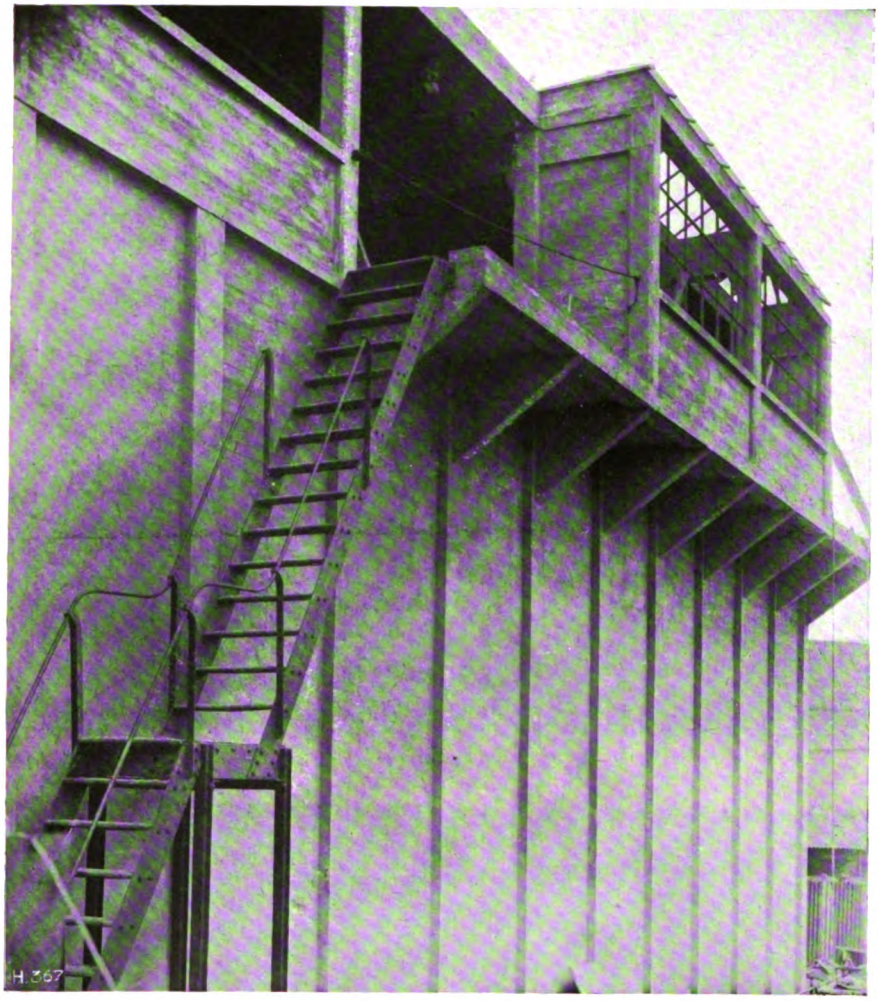
storing plumbago of varying degrees of fineness, access being obtained at the top of each bin by way of a manhole 15 in. sq.

The bins, as will be seen in sketch plan on page 508, have a height of about 27 ft. 6 in., excepting the packing bins over the packing gallery.

The hoppers of the bins are at ground level, the basement going about 8 ft. below that level.



REINFORCED CONCRETE MILL AT BATTERSEA.
View of cantilever loading platform.

An interesting feature in the structure is the cantilever work, and the loading platform also claims particular attention.

The centering consisted of wrought and close-jointed boarding, and the portion for the bin walls was made collapsible. By adopting this method, sufficient centering was needed for a height of 2 ft. 6 in. only of the walls, this being taken down and re-erected as the work proceeded.

Each time the centering was taken down it was cleaned and well greased, thus leaving a close and even face to the concrete.

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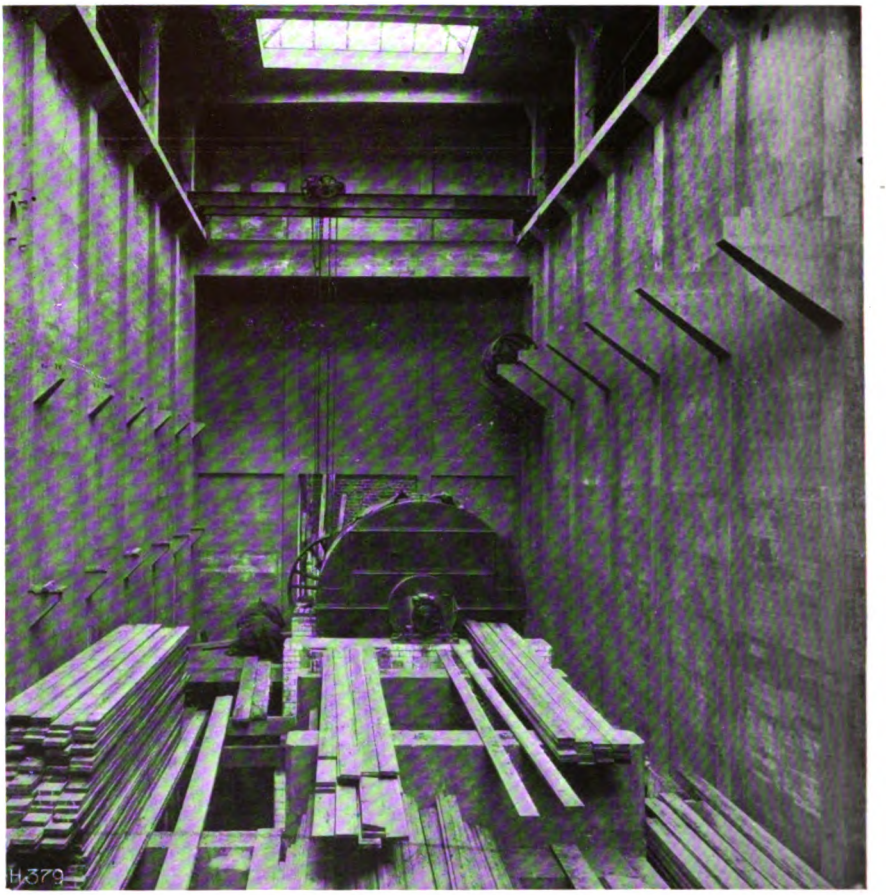
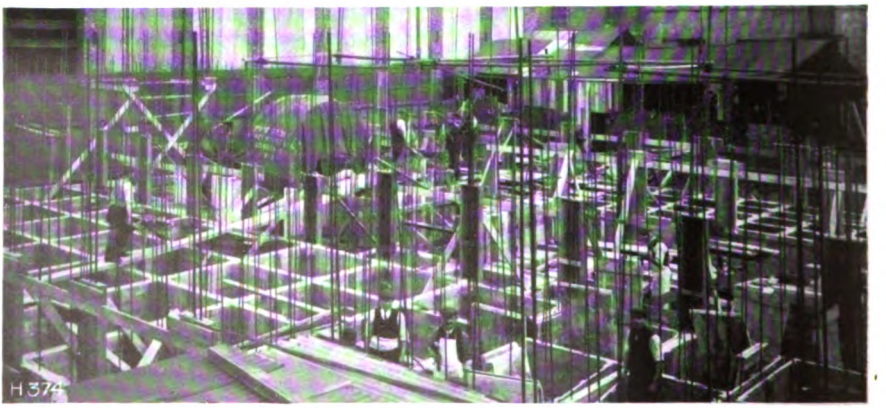


View down centre of mill.



Work in course of erection.

REINFORCED CONCRETE MILL AT BATTERSEA.

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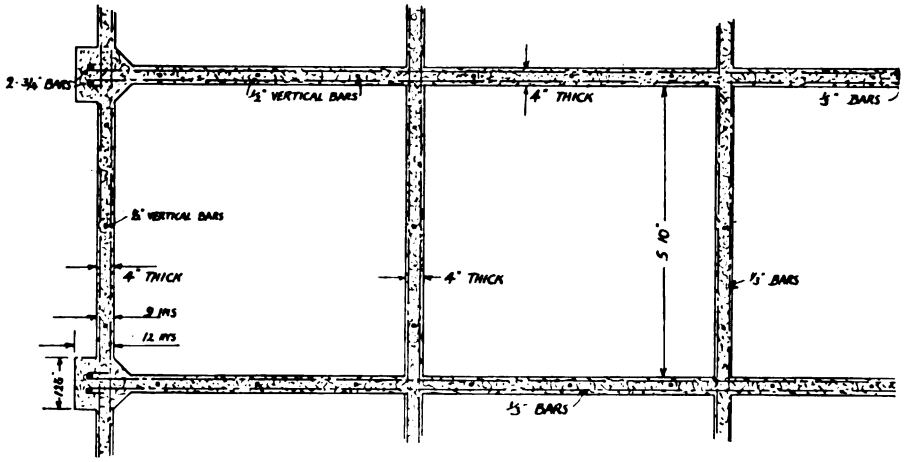
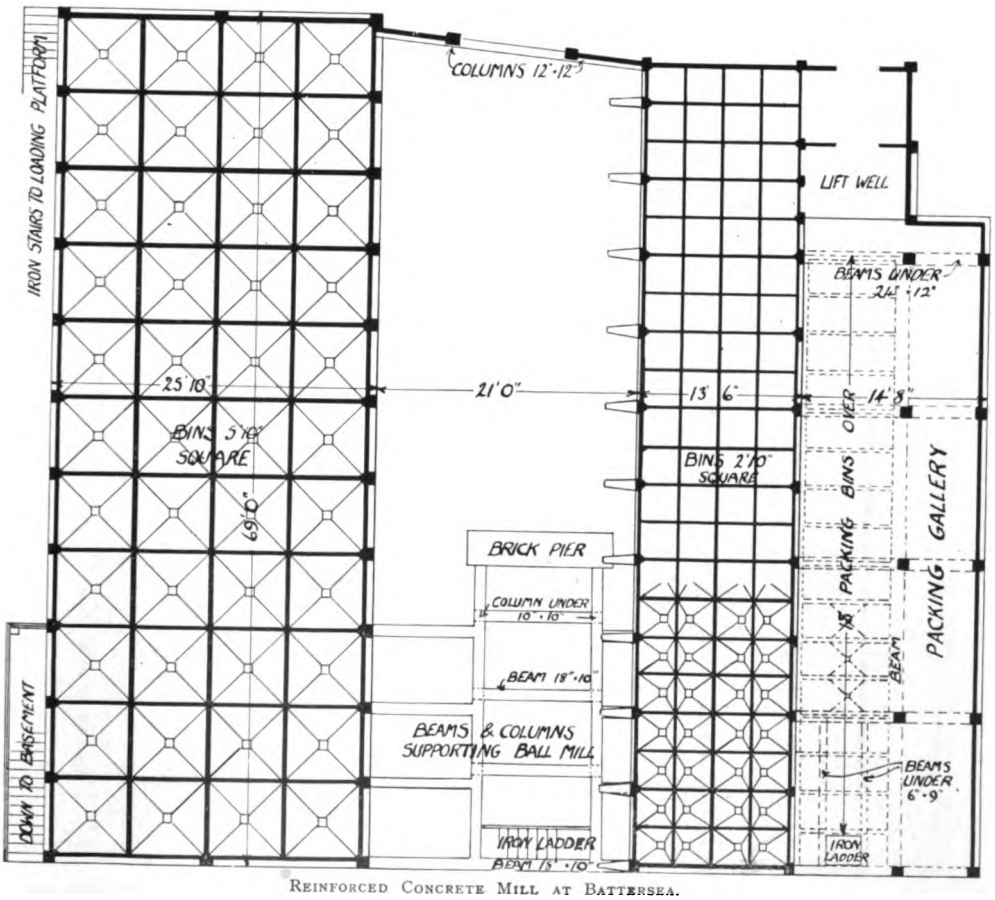


Detail plan of large bins.



REINFORCED CONCRETE MILL AT BATTERSEA.

General plan.

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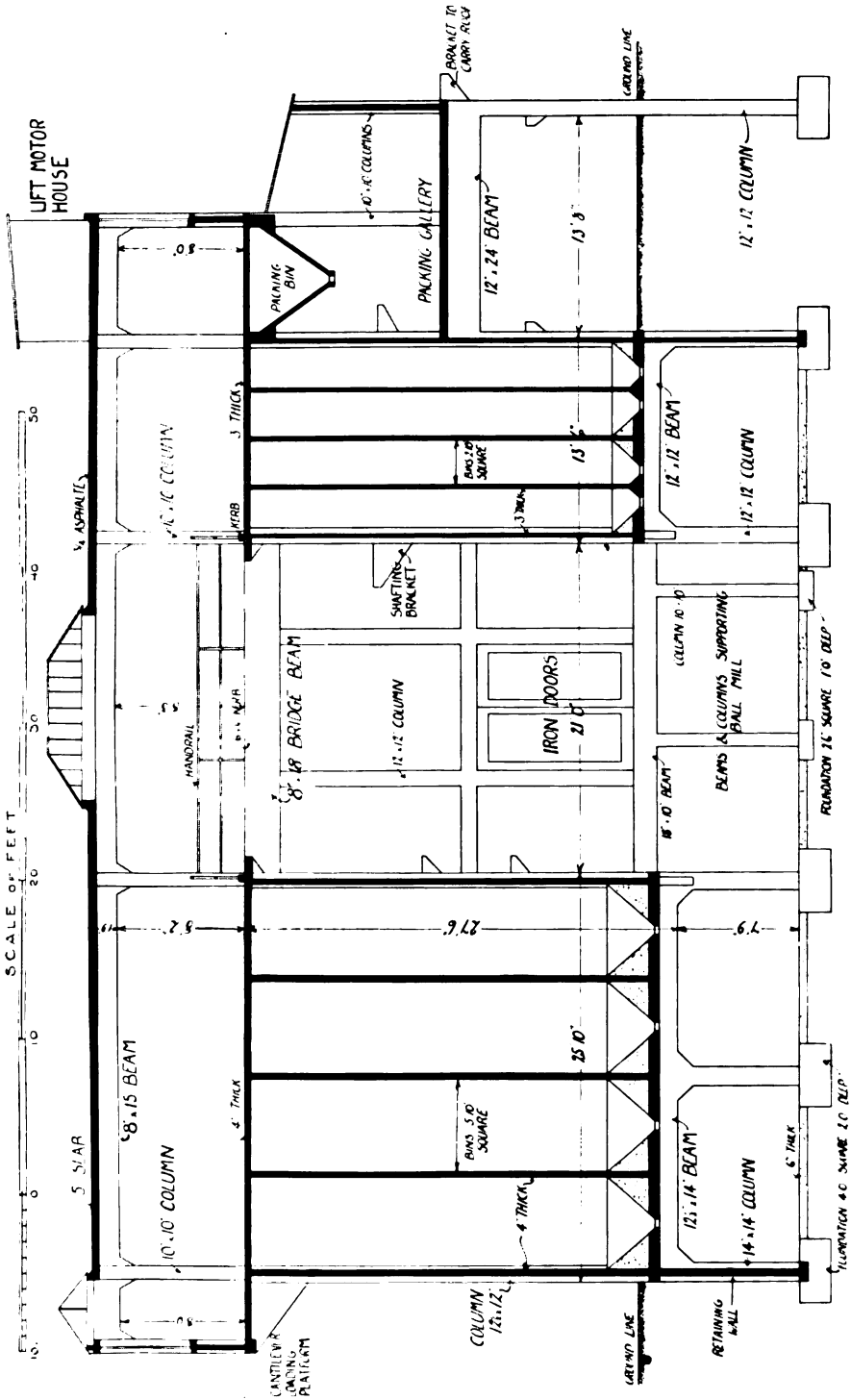

REINFORCED CONCRETE MILL AT BATTERSEA.
Section through mill.

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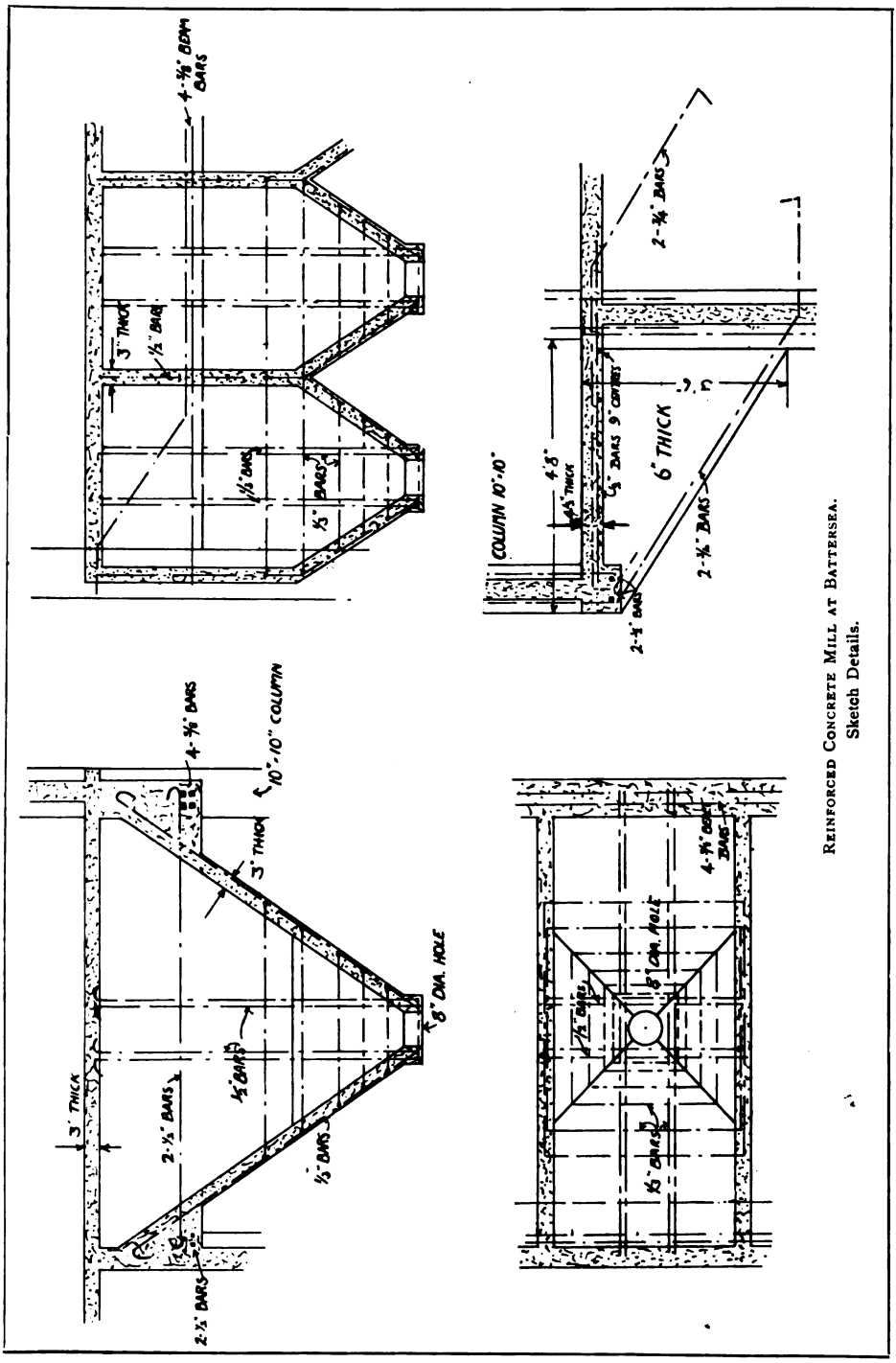

REINFORCED CONCRETE MILL AT BATTERSEA.
Sketch Details.

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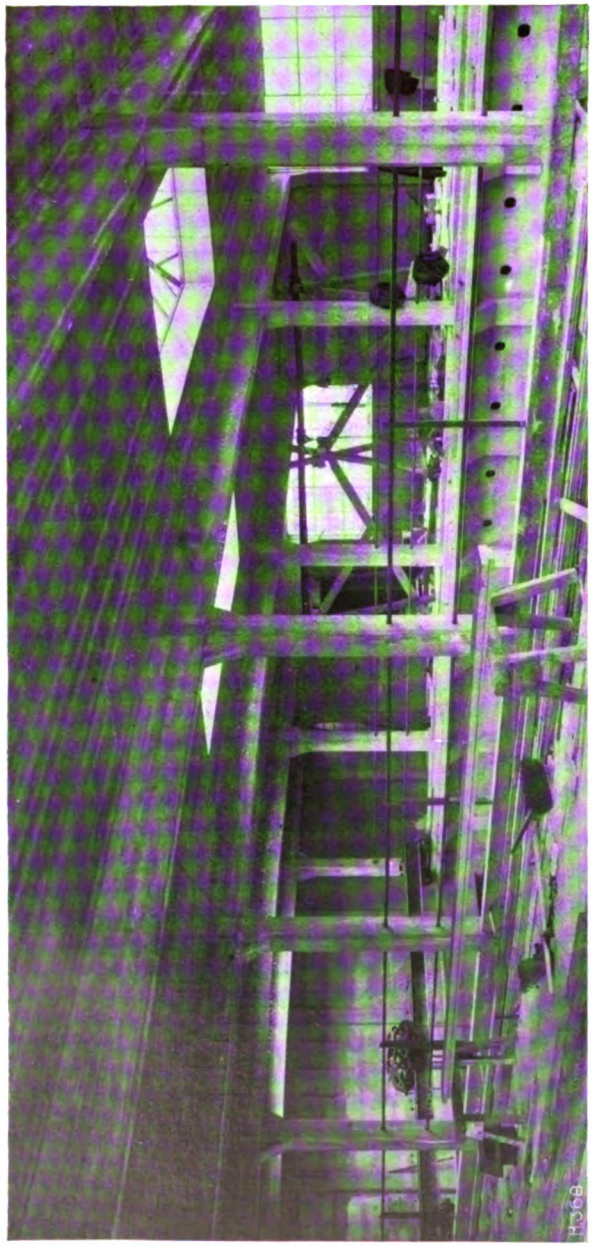
Provision was made for the installation of a "Waygood" lift with automatic locking gates at the different floor levels.

It will be noticed in the view down the centre of the mill that a large number of cantilever brackets have been constructed; these are to support shafting which drives the grinding machinery. Provision also was made for supporting an overhead travelling crane over the centre portion of the mill.



Reinforced Concrete Mill at Battersea.
View of the Upper Floor.

The roof was finished with $\frac{3}{4}$ in. of Limmer asphalt, and the skylights were formed of Patent Glazing with wire-woven glass.

Attachments for outlets to bins, shafting, electric light conduits and doors, etc., were built in the concrete as the work proceeded.

A concrete staircase was provided down to the basement, and iron staircases, with patent rubber treads, were provided at other points in the building.

The concrete throughout was mixed by machinery, and consisted of 4 parts of clean $\frac{3}{4}$-in. to $\frac{1}{4}$-in. graded Thames ballast, 2 parts of Thames sand, and 1 part of Portland cement to British Standard Specification, the columns having an additional 25 per cent. of cement. For the walls a finer aggregate was used, the Thames ballast measuring $\frac{3}{8}$ in. to $\frac{1}{4}$ in. graded.

The concrete was mixed fairly wet, and was left with a fair face from the centering.

THE NEW METEOROLOGICAL OBSERVATORY AT BLUE HILL.

The Blue Hill Observatory was first established in 1885 by the private enterprise of A. Lawrence Rotch, now Professor of Meteorology in Harvard University. The original structure, built of granite, proved inadequate for the work to be carried on

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and unserviceable as regards the admission of driving rain through its joints, and it was decided that a new Observatory should be erected in reinforced concrete. The architect was Mr. George T. Tildon, of Boston, and the contract was awarded to the Aberthaw Construction Co., also of that town.

The observatory is of circular section, 17 ft. 6 in. inside diameter, 20 ft. 6 in. on the outside, and 33 ft. high. The walls are of double thickness of 4 in. each, separated by a 10-in. air space, which provides an absolute means of preventing the passage of water.

Reinforced concrete was selected on account of its many advantages, important among these being its unyielding stability, freedom from vibration in high winds, and

REINFORCED CONCRETE MILL AT BATTERSEA.
Detail showing Hoppers.

its water-tight qualities so necessary in a location where wind velocities range up to 80 and even 100 miles per hour. Expectations have been so fully realised that the action of the self-recording instruments has been entirely free from the unknown errors which were caused by the rocking of the old observatory, and there have been no signs whatever of leakage.

The observatory is built on a ledge, the walls being bonded thereto, and the floor is slightly raised to provide an air space beneath. A separate 4-in. granolithic finish was put on top of the first floor to provide a smooth tread, as well as to prevent any possible access of moisture. The general concrete mixture was 1 : 2 : 4.

Steel reinforcement consists of $\frac{1}{4}$ in. sq. twisted bars spaced 9 in. on centres,

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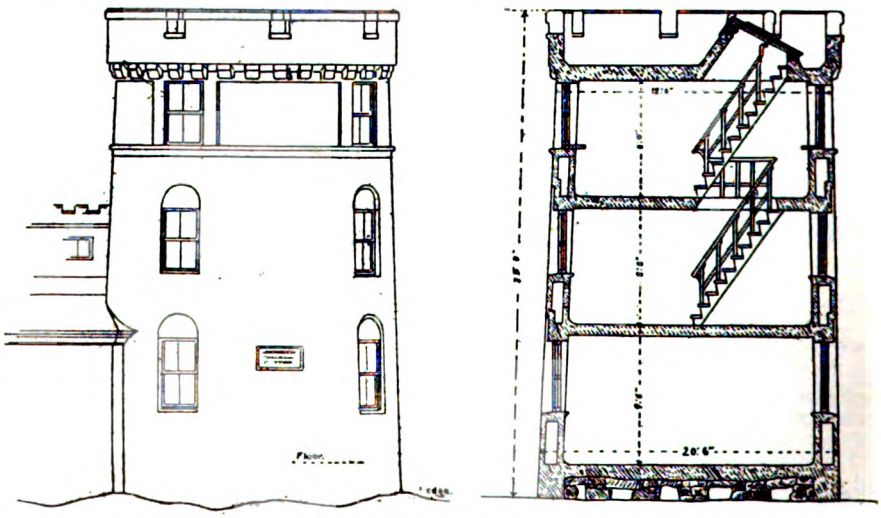
BLUE HILL OBSERVATORY.
(General view of completed tower).

running in directions at right angles to each other, embedded in the concrete near the surface, and extending into the wall.

The second and third floors and the roof are 6 in. thick, reinforced with ½-in. sq. twisted rods at right angles to each other and projecting into the wall. Those for the second floor vary in spacing from 12 in. on centres at the circumference to 5 in. apart at the centre. Steel reinforcement for the third floor and roof is practically identical with that of the second floor, but with an added number of bars at each side and at the middle end of the stair openings and roof scuttle. The reinforcing bars are placed close to the bottom of the floors, while those for preventing cracks close to the wall are placed near the top, being bent up at the wall and hooked over the nearest inside horizontal wall bar. All floors, including the roof, are granolithic finish; the latter is pitched towards the two water-ways which connect with the drain-pipes.

The inner and outer 4-in. walls are reinforced to the height of the second floor by ¼ and ⅜-in. twisted bars. Above this ¼-in. bars are used entirely, except where the ⅜-in. bars are placed for strengthening the flag-pole socket. Concrete webs at 3-ft. intervals connect the inner and outer walls, reinforced and connected to them by Z-bent ¼-in. bars.



PLAN AND CROSS SECTION OF NEW REINFORCED CONCRETE TOWER.
BLUE HILL OBSERVATORY.

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NEW USES FOR CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented as to new uses to which concrete and reinforced concrete are put, with data as to experience obtained during the experimental stage of such new applications of these materials. The use of reinforced concrete as a substitute for timber in exposed positions is one of the questions of the moment. Railway sleepers, telegraph posts, fence posts, etc., of concrete are being tried. Similarly, efforts are at present being made to prove that reinforced concrete is an excellent substitute for brickwork, where structures of great height are required.—ED.

A CONCRETE INDUSTRIAL VILLAGE.

The village of Mineville, N.Y., is inhabited chiefly by employés of a large iron ore company, and formerly consisted almost entirely of wooden buildings, as the company owns many thousand acres of timber land near the mines and lumber was until recently the cheapest material.

A few years ago, however, the general manager of the company began experimenting with concrete blocks, and these experiments were so successful that now nearly all the important buildings on this property are built of concrete, and about fifty workmen's houses have been erected of the same material and more are in process of construction.

It should be stated that one of the factors that led to this extensive use of concrete was the possession by the company of a very superior aggregate in the shape of "tailings" or residue left after the separation of the ore. Tests have proved that cement mixed with the run of tailings in the proportion of 1 to 5 produces a very superior concrete block without the addition of sand or gravel.

The initial cost of the concrete block workmen's houses built by the company is about the same as lumber, but with the decreased cost of maintenance they are far cheaper in the end. All block walls are furred with an inch strip of wood lath, and no trouble is experienced from moisture. The houses are warm and comfortable during the severe winters, some of the smaller ones being heated only by the family cooking stove.

The illustrations presented herewith give a good idea of different types of concrete construction employed by the company.

Fig. 1 is a seven-room tenement house, 15,611 cub. ft. contents. Cost of building $1,100 (£200), or 3½d. per cub. ft. Walls are of blocks with stucco exterior.

Fig. 2 is a type of six-room workman's house. Contents 11,561 cub. ft. Cost 4½d. per cub. ft., interior trimming included.

Fig. 3 is the police station, which is of monolithic construction, solid walls, no reinforcement being used. The building is 28 by 24 ft. Cost of building was $3,200 (£640). Heating and plumbing $400 (£80) extra.

Fig. 1. Seven-Room Tenement House.

Fig. 2. Six-Room Workman's House.

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Fig. 4 is a well-designed double house. Size 29 ft. 4 in. by 52 ft. 4 in. Contents 31,223 cub. ft. Cost $4\frac{3}{4}$d. per cub. ft.

FIG. 3. POLICE STATION.

FIG. 4. DOUBLE HOUSE OF CONCRETE BLOCKS.

Fig. 5 shows a row of the first concrete houses built by the company. These are of 15,017 cub. ft. contents each. Size 25 ft. by 22 ft. Cost $4\frac{1}{2}$d. per cub. ft.

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Around the office building at Mineville the company has built a driveway 600 ft. long, 14 ft. wide, and 5 in. deep, using a mixture of 12½ parts ore tailings to 1 of

FIG 5. FIRST CONCRETE HOUSES BUILT AT MINEVILLE, N.Y.

cement. This driveway has withstood 2½ years' traffic without showing signs of deterioration.

It is practically certain that the company will build no more permanent structures of wood, and as the existing wooden buildings are replaced from time to time with concrete Mineville will present the spectacle of a village built entirely of concrete.

We are indebted to the *Cement Age* for our illustrations.

REINFORCED CONCRETE POSTS.

We have dealt in previous issues with the use of reinforced concrete for fence posts, and now give some further illustrations of posts for a large cattle pen which was put up for a firm of estate agents by Mr. E. F. W. Grimshaw, of West Mill, Buntingford, Herts.

The posts are 4 ft. 8 in. high, 6 in. by 6 in. at top, and 7 in. by 7 in. at base. They are first set in holes, 6 in. of concrete is put in, then clay stuff, and finally about 8 in. of concrete up to surface.

So far this fence has proved most satisfactory, and it is very cheap compared with those made entirely of iron, the cost being about 13s. per yard complete.

The question of applying reinforced concrete posts to general estate and farm work claims the closest attention from those to whom the expense of the maintenance of fencing has become a serious burden.

REINFORCED CONCRETE FENCE POSTS.

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INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

REINFORCED CONCRETE FOR FARM BUILDINGS.

THE farm building, of which we present illustrations, has been built on a new system designed for building cheaply in reinforced concrete.

The plan of this building is that of three sides of a square, two sides being of one storey, while the other, in which are situated the fodder room, stables, and a loose box, has a granary and loft overhead.

The system employed of forming the sides and party walls flat on the ground and afterwards raising them up and jointing at corners and where party walls meet outside walls, lends itself to cheap and quick construction, and the use of reinforced concrete renders this construction possible.

In designing the system simplicity of moulding and erection has been the chief point kept in view, also the necessity for the different parts to come up exactly in place for fixing together without any further adjustment.

The method adopted consists in moulding the segments of building on platforms, which are temporarily hinged in a way to be described, then rearing the platforms with segments on them to a vertical position, lowering away the platforms for use with other sections, and finally securing the segments together.

The hinges are made of ¾-in. bar iron bent into hoops with the top about 4 in. across and long ends 2 ft. A number of these are placed in a row and blocks of concrete 1 ft. cub. cast round them. These blocks are simply to keep the hinges upright and in position in the foundation trench while foundation is being built around them. They are just the weight a man can easily handle and heavy enough to remain where he puts them while he builds up to them or tamps concrete around them.

The platform is laid on light girders, I section, which have hooks attached at one end for hooking on to the top of hinge; the drop of the hook is set so that the top of platform, made of boards—say, 1½ in. thick—when laid on girders, comes level with the centre line of top part of hinge. On the platform is moulded the section of building.

It is clear that if the girders with platform are now reared up the section of building must come exactly into its proper place, the face next to platform being the outside of building, and if the hinges are set in line the section must be true. It will be noticed that the weight of the section when, say, at an angle of 20° from vertical is borne by the hooks until it is safely placed on the foundation, when the platform is lowered away and girders unhooked.

In setting out the foundation no time is lost. For a square building four lines are stretched to dimensions of outside of building, the lines being, of course, level and square; then the hinges are put down at any convenient points along the line and up to level; no matter where they are along the line the section when erected must come into its proper place.

In building or concreting the hinges in place a channel is left where the girders will come. This is easily done by having a temporary piece of wood the required shape to represent the girder while building or concreting, the surface of foundation being purposely left 2 in. or so below the required bed level.

After the section has been moulded and is setting, in order to get the part where it will rest to exactly the proper level, it is only necessary to dump down some concrete and strickle it off from the face of the section, now lying flat, with a notched board the same depth as thickness of section, thus avoiding all levelling with staff and spirit level.

The erection of the segments is done by winches, generally equal in number to

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VIEWS SHOWING METHOD OF CONSTRUCTION.

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the hinges used, a joist being put under all the ends of girders and the ropes attached to that, the men being careful to turn together so that the lift may be uniform. There is a back-pull winch to prevent going beyond vertical. Suppose there are three winches used, as was the case in gable end, when section is vertical two props are placed under the top flange of gable or any projecting part, and the centre winch made fast to a couple of pieces of bent iron cast near the edge for this purpose and also for attaching the sides when they are erected. This winch then pulls against the props and the other two can "lower away"; the platform then comes away and is taken to pieces, the girders are unhooked, and props placed to support the other side. These props bear against the pieces of wood put through holes which are left by the blocks supporting the parts of mould forming the flange, or the holes may be left purposely and pointed up when finishing off the building.

Paper is laid under the concrete so that it will not stick to the mould. This paper can be had in rolls, costs very little, and is easily applied.

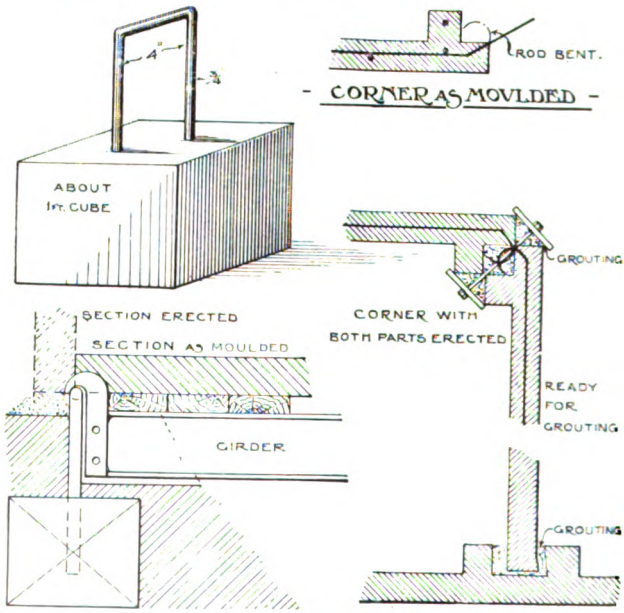
The corners of building are jointed and strengthened as follows:—In moulding there is a flange cast at some distance (generally equal to thickness of section) from the edge, and the reinforcing bars are prolonged through for some distance. When cement is set the ends are bent round to circle and it will be seen that the two sections coming together allow boards to be put on each side of joint, the whole grouted in, thus a strong pillar for corner is made, as well as a tie for the sides.

Party walls are joined to sides by a simple dove-tailed joint grouted in.

The wall-plates are made of coke breeze concrete to enable the rafters to be nailed direct on to the walls—saving timber wall-plates.

When commencing the mould the girders are hooked on to the hinges and their free ends supported on pieces of timber laid direct on the ground; they are then brought up to level in a few minutes by means of folding wedges. The boards are then laid on and the outline of section made with spars that will be used afterwards for the rafters, and pillars are outlined in the same way, the stuff being used again for another section when concrete is a couple of days old.

A doorway is formed by simply laying the door itself flat on the platform in its proper place with hinges and latch all complete and casting the concrete around it. Thus no door posts or jambs are needed, thin pieces of wood ¼ in. thick are tacked round the door, and these give clearance for the door to open or shut; there is consequently no fitting of any description whatever.



DETAILS OF CONSTRUCTION.

The walls of this building are 3 in. thick with 6-in. pillars, cement and fine gravel 4:1, reinforced with ⅜-in. bars spaced 12 in. each way. They can be built at very little more per yard super. than cost of a floor of concrete 3 in. thick. The raising of walls is a very small item. The total size of building walls is 3,668 super. feet; floor space is 1,620 super. feet, and cubic contents 22,772 ft., measured inside and to floor level only. The total cost of erection and fitting

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inside complete is £256 10s. 6d., as against £414 for a similar structure which was built of stone, the stone being supplied free.

Further particulars of the system, which has been provisionally protected, can be obtained from H. W. Buddicom, M.I.Mech.E., Penbedw Estate Office, Mold.

WOLLE'S REINFORCED CONCRETE "SAXONIA POST."

THE transmission of powerful electric currents to great distances is a necessity of the present day, the exclusive use of electricity for railways is a mere question of time, and the construction of electric tramways is increasing year by year. For all these purposes, as well as for telegraph and telephone services, enormous quantities of posts are required.

The renewal of wooden posts and wood telegraph poles, which are being destroyed by dry rot, worms (white ants), wind pressure, etc., involves a loss of millions of capital; furthermore, good wooden posts are getting scarce and are constantly increasing in price.

In the case of iron posts the initial outlay is heavy, in addition to which they require constant supervision and frequent renewal of paint to prevent corrosion, whereby considerable maintenance expenses are incurred. The necessity has, therefore, arisen to construct posts of a material which, whilst capable of sustaining the required strain, is less expensive than iron and proof against the action of the weather, frost, etc.

Reinforced concrete has been justly recognised as the material which is unsurpassed for sustaining the strains of tension and compression, which is unrivalled as regards durability in any kind of weather, and which possesses an almost unlimited durability.

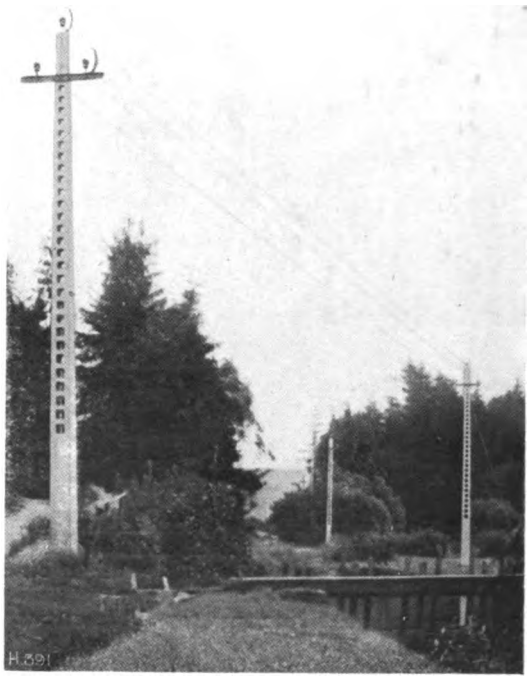
Reinforced concrete has proved to be highly satisfactory for the construction of poles, but its general introduction has been up to the present prevented by the heavy cost of manufacture, by the serious technical defects—such as the impossibility of climbing without the aid of ladders, whereby the operation of fitting is rendered difficult and its cost increased—and by the difficulty to guarantee the requisite factor of safety of four of the construction.

All these defects and drawbacks have been skilfully avoided with Messrs. Wolle's Saxonia Post, the construction of which is suited to the nature of reinforced concrete. The main advantages claimed for the Saxonia Posts are :—

(1) Simple and easy manufacture in cheap wooden moulds, without the employment of expensive machinery. The manufacture can be made at a factory or near the place where the posts are to be erected.

(2) The cost of manufacture is low. Under normal conditions the prime cost of Saxonia Posts is lower than that of iron lattice posts or tubular iron posts.

(3) The Saxonia Post is imperishable and requires no attention for maintenance.



"SAXONIA POSTS," REICHENBACH.

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In the long run it is thus much more economical than even wooden posts, which latter possess the serious drawback of deterioration.

(4) The Saxonia Post is constructed strictly in accordance with approved statical calculations; the requisite factor of safety of four can, therefore, be guaranteed.

(5) Owing to its perforations the Saxonia Post is climbable, and the expense of carrying long ladders for the purpose of fitting wires is avoided. To prevent

"Saxonia Posts," Irchwitz.

climbing by unauthorised persons the portion of the post about two yards from the ground is made without perforations.

(6) The comparatively light weight of the Saxonia Post renders its transport possible to great distances. The possibility of manufacturing the posts on or near the spot where they are to be erected effects a very considerable saving of freight.

(7) The erection of the Saxonia Post is effected by simple means.

(8) The Saxonia Post is attractive from an architectural point of view.

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The many distinct advantages of the Saxonia Post, combined with its low cost of production, have appealed greatly to the authorities on the Continent. In Germany alone more than 3,000 Saxonia Posts have been erected during the last few months, and further contracts for more than 4,000 Saxonia Posts have already been secured. Amongst other contracts may be mentioned the Overland Central Electricity Works, of Reichenbach, in Saxony, where 2,000 Saxonia Posts have been erected; Ringelheim (about 2,500 posts), Goettingen, Wilhelmshaven, Burgsdorf, Glauchau, Oberkirch, and many others.

The Saxonia Post has been used with great success as posts for arc lamps, amongst other places at Fuerth, Oppeln, Schwerin, Kiel, Oldenburg, etc.

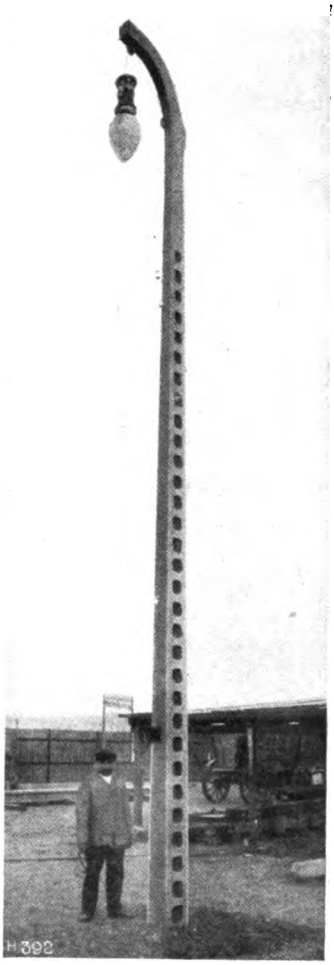
Testimonials from leading engineers may be inspected.

The success with which the new construction has met in other parts of the world will ensure its speedy introduction into this country. Considerable interest in this new and useful construction, which is evidently a great improvement on all reinforced concrete poles hitherto known, has already been aroused in engineering circles in England. There is no doubt that the Saxonia Post will be welcomed in the Colonies, where the quick deterioration of wooden posts and the heavy cost of iron posts make the use of a simple reinforced concrete post particularly desirable.

The patentee, Mr. Rud. Wolle, Cementbaugeschaeft, Leipzig, has already established 29 license branches in Germany, Switzerland and Belgium.

The Saxonia Post is patented in Great Britain and the principal British Colonies.

Particulars as to license terms may be obtained from Mr. Wolle's representative in London, Mr. E. von. Mandelsloh, 70, Finsbury Pavement, E.C.



"Saxonia" Electric Light Standard, Leipzig.

HOLLOW REINFORCED CONCRETE POLES.

About four years ago the firm of Deutsche Schleuderröhren-Werke Otto & Schlosser in Meissen on the Elbe commenced to manufacture hollow reinforced concrete poles by applying centrifugal force.

The following is a brief outline of the process. To prevent separation of the Portland cement and sand the concrete is mixed with a small quantity of asbestos fibre. The mould into which the concrete (about 1 :3) is poured consists of large wooden planks lined with sheet metal and linked together along the long sides.

An iron frame for reinforcement is put into the mould before filling it up. The frame follows the outline of the hollow post exactly and is just a little smaller than the finished post itself. It is made up of long rods (round sections of Siemens-Martin steel) and an inner and outer spiral coil, which rigidly hold the rods in position.

Very accurate patterns and reliable machinery are employed for making the iron structure, so that all parts are made to fit into one another with perfect precision. The frame must, of course, be held centrally inside the form, so as not to obtain a one-sided structure. This is done by means of a number of small concrete blocks, which are attached at different points all round the rods by wires. These blocks serve as distance pieces during erection, as well as during the centrifugal process afterwards.

After having securely fixed the ironwork inside the mould the concrete is filled in, whereupon the mould is brought on to the centrifugal machine, which is illustrated on page 524. It will be seen that the machine consists of a row of units, which are all

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alike, and are situated at certain intervals from one another. Each unit is made of two strong side shields with a circular hole in the centre.

There are three shafts arranged concentrically round the hole, and at equal distances from one another, the bearings being provided with a radial adjustment. The mould is passed through the holes in the centre of the shields and is held in position by two rollers on each shaft; besides this the mould is fitted with self-centering screw clamps, similar to those used on lathes.

Before the centrifugal process commences the supports are adjusted properly, and the mould is pushed into the clamps and through the holes from one end. After that the clamps are tightened up and centered. After having lowered the frame support in the centre so that the mould rests entirely on the rollers the machine is started up. The shafting is driven by an electric motor; the speed varies according to circumstances and may be anything between 500 and 1,000 revolutions per minute.

The centrifugal force set up during the rotation of the mould presses the concrete against the iron framework and gradually produces a firm concrete cover. Water is separated from the concrete and collects inside the post, and takes part in the rotation of the mould and presses against the inner surface of the concrete. The revolving movement forms the pole, presses the concrete, and removes the moisture it contains quite automatically; the whole process is finished in a few minutes. According to the thickness of the concrete sides the machine must run from 10 to 15 minutes.

The pole remains in the mould about 12-24 hours, after which the concrete is set sufficiently to enable the pole to be removed. It is then hardened gradually in sand, which is kept moist, until it is properly set in about three or four weeks.

The usual shape of poles is conical, with a gradual and even taper from top to bottom, this being the natural shape to meet static stresses. To make these poles a conical hollow mould is required. With a horizontal axis the compound will settle at the larger end more than at the smaller one, so that the thickness is greater at the bottom than at the top, which is just what is wanted. When it is desired to make a post with an even thickness of concrete the axis of the conical mould should not be horizontal.

These reinforced hollow poles are now made in one cast in lengths up to 14 m. (45 ft. 11 in.), but there are no technical difficulties to prevent even longer ones being made. The diameter at the top is now from 15 to 22 cm. (6 in. to 8½ in.), and that at the bottom from 22.5 to 37 cm. (8¾ in. to 14½ in.). The thickness varies according to stresses; it is made from 3 to 9 cm. (1⅛ in. to 3½ in.).

Reinforced concrete poles always remain exactly the same, which is their chief advantage compared with those of wood or iron. The durability of wood is limited, because it rots, and iron poles are expensive and require continual inspection and periodical renewal of the protective coating. In the case of the reinforced concrete poles we are describing the iron is completely embedded in the concrete, which affords a permanent protection. A peculiarity of the concrete is that its strength increases considerably in the course of time. It should also be mentioned that the strengthened circular section is favourable for the full use of all material employed and has a moment of resistance which is equal on all sides. Insulators, brackets, etc., can be attached to a circular post in any position, in the same manner as to wooden or iron ones with a similar section.

These reinforced poles are not only supplied from the works ready made; they can also be made on the spot, because the process is so very simple and the machines take up very little space and require a small amount of power; the raw material of which they are made is also to be found everywhere. From this point of view concrete poles are without doubt the most convenient for railway and power line construction in foreign and colonial countries. They can be made quite easily in any place, no specially skilled men are required, and there is every possibility of being successful.

The Royal engineering laboratory in Dresden was authorised by the Deutsche Schleuderröhren-Werke Otto & Schlosser in October, 1908, to subject the poles to scientific tests. Although only a small number—three—were tested, the results were so much the same that one can judge them all from those tested, especially as the poles are turned out wholesale and are made exactly alike.

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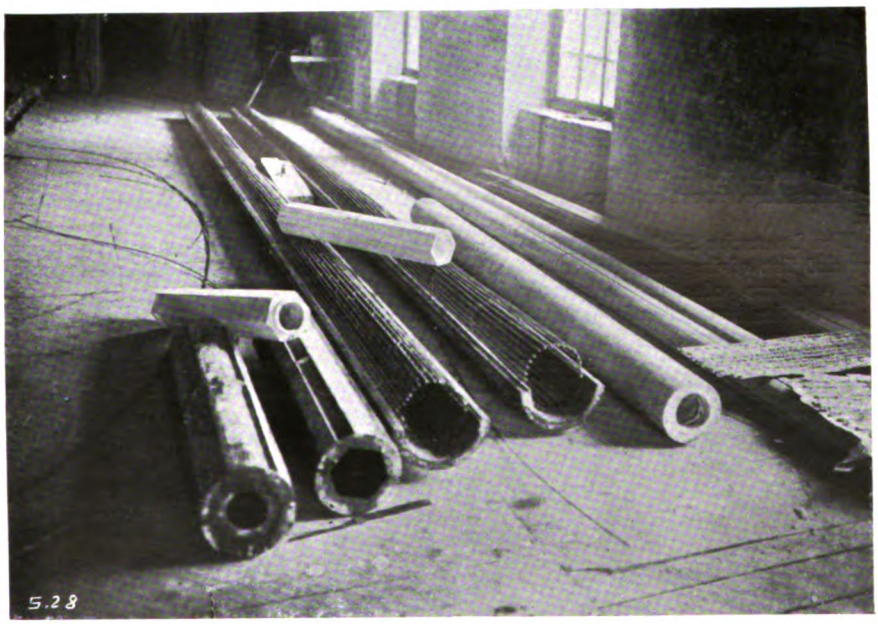

HOLLOW REINFORCED CONCRETE POLES AT OTTO & SCHLOSSER'S FACTORY, MEISSEN

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The concrete in the poles tested consisted of 32 kg. (70 lbs.) of cement, 245 kg. (540 lbs.) of sand, 8 kg. (17½ lbs.) of asbestos fibre, and 68 kg. (152 lbs.) of water. The iron skeleton consisted of 16 rods, which were 9 m. (29 ft. 6 in.) long with a diameter of 6 mm. (¼ in.) and 15 rods of similar size but 6 m. (19 ft. 8 in.) long. The concrete was set in moist sand, the tests were made ten weeks after completion, and the process in the centrifugal machines did not last longer than ten minutes. The long rods were held in position by an outer and an inner wire coil made of 3 mm. (⅛ in.) wires.

In the first test the position of the pole was horizontal and the thin end was bent upwards. In the second and third tests the poles were treated as they would have been in actual use.

In the first test a weight of 550 kg. (1,212 lbs.) was attached to the top of the pole; it produced a total deflection of 1.10 m. (3 ft. 7 in.) without causing breakage. In the second and third tests the pull at the point was horizontal and amounted to 541 and 505 kg. (1,192 and 1,113 lbs.) respectively, and the deflection was 1.18 m. and 1.13 m. (3 ft. 10 in. and 3 ft. 8 in.) without causing breakage.

The results of these tests were considered most satisfactory.

CENTRIFUGAL MACHINE.
Used by Otto & Schlosser for making reinforced concrete poles.

The Deutsche Schleuderröhren-Werke Otto & Schlosser in Meissen have published a special list giving particulars of prices; they are about halfway between prices for wood and iron poles for the same pull.

The poles have already been approved in practice in many places and under a large variety of conditions.

For further particulars regarding these poles and also concerning the patent rights for the United Kingdom and the Colonies, application should be made to Mr. Richard Bockemuhl, 190-2, Great Portland Street, London, W.

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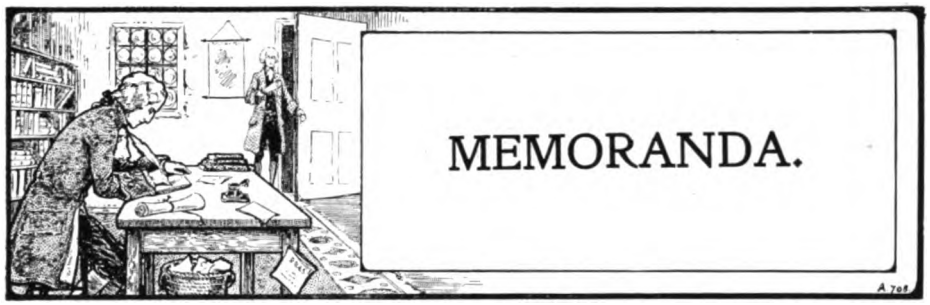

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

SUITABLE UNITS FOR REINFORCED CONCRETE WORK.

As the matter of standard notation and suitable units for calculations in reinforced concrete is receiving considerable attention at the moment, we are giving an extract from a paper read some time ago by Mr. E. Fiander Etchells, F.Phys.Soc., M.Math.A., before the Civil and Mechanical Engineers' Society :—

When the designer of steelwork first turns his attention to the design of reinforced concrete structures he is struck by the unsuitability of the units for the purposes of mental calculation.

A steel section book and a sheet of paper might serve for the designing of an ordinary steel skeleton for a building so long as the designer had only himself to satisfy, and so long as there was no necessity to keep a written record of his mental processes. But in the case of reinforced concrete construction the formulæ are more complex. There is as yet so little real standardisation, and the "inch-pound" unit is so small, and the numbers met with are consequently so large, that mental arithmetic breaks down, and quires of paper must be called into requisition even to satisfy oneself.

The ideal would be to be able to stand amid the centerings and scaffoldings of a building during construction and by inspection to know within a small amount what the beams and pillars would safely carry. This is often possible with steel work, and it is the engineer's duty to make it possible in the case of reinforced concrete.

One step in this direction would be to omit the hundreds and thousands ciphers from the figures involved in the calculation.

Each engineer can do this for himself without waiting for the decision of a Royal Commission, or even that of the Engineering Standards Committee.

The first unit for your consideration is the *cental—i.e.*, 100 pounds avoirdupois.

This is not an innovation in itself; the only innovation consists in its use for reinforced concrete work, and for this it is eminently suitable.

The "cental" is the same as the American hundredweight. It has been used in the Liverpool grain market since 1859, but in 1878 it was proposed for general adoption, and its use in England was legalised by Act of Parliament. As an illustration of the pre-eminent suitability of the proposed unit I will convert the working stresses recommended by the Reinforced Concrete Committee of the Royal Institute of British Architects into centals :—

	lbs.		Cwts.		Centals.
Weight of reinforced concrete per cu. ft.	150	=	1·34	=	1·5
Concrete in compression in beams, subject to bending, per sq. in....	600	=	5·35	=	6
Concrete in pillars, under simple compression, per sq. in.	500	=	4·45	=	5
Concrete in shear in beams, per sq. in.	60	=	·536	=	0·6
Adhesion of concrete to steel, per sq. in.	100	=	0·89	=	1

I submit that the use of the "cental" will conduce to safe and rapid mental working.

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The second unit is the "milal" = one thousand pounds avoirdupois = ten centals. This unit is a natural development from the pound and the "cental." It is one half of the American short ton. You may call it what name you will; I have called it "milal," having in mind the Latin root "mille"—a thousand—just as "cental" is derived from "centum."

The "milal" will be found useful for moments of resistance, for the figures often run up into thousands of inch-pounds, even for slabs 5 in. or 6 in. thick.

For example, instead of 32,000 inch-pounds we should write 32 inch-milals. If anyone could not understand the simple "milal" he could easily put three noughts behind it and call it so many thousand pounds.

If the "milal" does not commend itself to you do not on that account discard our older friend, the "cental." Then, by and by, you will see the logic and the use of both.

The "milal" disturbs nothing and leads to no confusion, but it gives us a unit very suitable for mental calculation.

Although I submit that the suggested names are convenient and explicit I set no store by the names *per se*. The whole essence of the suggestion is in the simplicity of the units themselves, and in the avoidance of a multiplicity of unnecessary figures.

I have no antipathy to the ton nor to the metric ton, but inch-pounds are time-wasters :—

ILLUSTRATIONS FROM R.I.B.A. REPORT ON REINFORCED CONCRETE.

Property.	lbs. per sq. in.	"Milals" per sq. in.
Ultimate strength of steel	60,000	60
Modulus of elasticity of steel...	30,000,000	30,000
Modulus of elasticity of concrete	2,000,000	2,000
Working stress of steel in tension	15,000 to 17,000	15 to 17

GENERAL.

Bridge over the Trent.—The Cleveland Bridge and Engineering Company, Ltd., of Darlington, has been awarded, by the Lincoln City Corporation, the contract for the construction of a bridge and aqueduct over the river Trent at Dunham bridge, about ten miles distant from Lincoln. This work comprises a bridge of six spans—one main river span of 265 ft. and five spans each of about 65 ft. The abutments on both sides will be constructed within cofferdams and carried down to a depth of about 40 ft. The piers carrying the approach spans will be of reinforced concrete faced in ashlar, the foundations consisting of eleven concrete piles 15 in. square and varying from 30 ft. to 50 ft. in length. There is also included in the contract some reinforced concrete troughing required for carrying the water mains over the west approach side of the bridge.

Cardigan County Council and a Reinforced Concrete Bridge.—At a recent meeting of the Cardiganshire County Council the surveyor submitted plans and estimates of the proposed new bridge at Aberavon. He stated that an iron bridge would cost complete £1,400, and a reinforced concrete bridge £1,300. He asked them to adopt reinforced concrete, as it gave satisfaction to the northern district generally. After some discussion it was decided to accept the tender for a reinforced concrete structure.

Reinforced Concrete Bridge.—The Builth Wells U.D.C. have submitted to the Radnorshire C.C. a plan of the proposed new bridge at Newbridge-on-Wye. The plan provides for a structure of three equal arches in reinforced concrete, with iron handrailing with abutments and piers, faced with stone.

Bridge at Wexford.—The County Council has approved the proposal to erect a reinforced concrete bridge at Ferry Carrig, at an estimated cost of £5,150, in place of the existing defective wooden structure.

Reinforced Concrete Bridge at Abersychan, Mon.—Plans for the erection of a new bridge to span the Avon Lwyd have been prepared by the surveyer and approved

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by the Council. Owing to the dangerous state of the old structure it has been decided that the work shall be taken in hand at once, and that the new bridge, which will be of reinforced concrete, shall be erected on the same site as the old one.

A Long Reinforced Concrete Viaduct.—The Mulberry Street Viaduct in Harrisburg, Pennsylvania, which was recently opened to traffic, is constructed in reinforced concrete, and takes the place of an old iron structure which was damaged by fire some years ago. With the exception of the Pont d'Esprit, near Lyons, it is stated to be the longest arch road-bridge in existence. The main bridge work is 1,800 ft. long, and is constructed on concrete arches in spans varying from 40 ft. to 100 ft. in length, carried on piers of similar material. The bridge provides a 28 ft. roadway, with an 8 ft. pavement for pedestrian traffic on either side, while the approach to the bridge is 600 ft. long, with a 28 ft. roadway and a 6 ft. pavement. In referring at the opening ceremony to the enduring character of the work, Mr. James H. Fuertes, the designer, said that he had in his possession a wrought-iron nail of about three inches in length which had been used in the Roman Forum to secure the marble lining to the walls of a bath room. The nail had been so preserved by the mortar in which it had been embedded that, although buried 40 ft. below the surface, it was now practically free from rust, and after fully twenty centuries still retained some of the original mortar.

Concrete Telegraph Poles.—Experiments with concrete telegraph poles by the Pennsylvania Railway have met with such success, according to *The Engineer and Iron Trades Advertiser*, that it has been decided to extend their use over the Fort Wayne, Panhandle, and other lines west. No definite sum of money has been put aside for this purpose, but it is understood that the engineering department has been given orders to prepare to use concrete poles. The construction and improvement programme for 1910, which will be decided upon shortly, is expected to include orders to place many miles of concrete poles on the lines west.

Reinforced Concrete Boat.—Boatbuilders at Frankfort-on-Main have succeeded in making and launching a practical river barge made of reinforced concrete.

The stays and framework are of iron, the panels being of reinforced concrete, and all the metal is covered up with the concrete, so that none of it is exposed to the action of water or weather.

It is claimed that the cost of construction is 25 per cent. less than that of ordinary iron barges, while the life of the boat is lengthened and the cost of repairs reduced to a minimum.

The boat, just launched, is 130 ft. long by about 20 ft. beam, and draws thirteen inches of water without ballast. The builders are now busy on plans for motor boats of the same material, and, if successful, we may soon hear of ocean-going barges laid down on similar lines.

Tube Railway Platforms.—The platforms of the Central London Railway are being converted from wood to concrete, on the recommendation of the Board of Trade, in the interests of the greater safety of the travelling public. The recommendation in question was made as the result of the fire at the Moorgate Street station of the City and South London Railway, and the platforms at twelve stations of that company are being reconstructed in the same way.

TRADE ANNOUNCEMENTS, CATALOGUES, ETC.

The British Fibro-Cement Syndicate, Norfolk House, Laurence Pountney Hill, E.C., have sent us a nicely printed pamphlet, in which the special properties of fibro-cement sheets and roofing slates are set forth, the makers laying stress upon the lightness, non-conductivity, economy, permanence, and fire-resistance of this material. There are also general instructions on the use and storage of the roofing slates, together with diagrams and sketches illustrating the method of laying and fixing, with different patterns of slating, ridging, etc. The fact that insurance companies make a reduction of 25 per cent. when fibro-cement sheets are used to line buildings is quoted as an important testimony to the really fireproof nature of these goods.

"Patent Indented Bar Bulletin."—The November number of this publication gives a general specification for reinforced concrete work, in which is embodied much useful information. There is also a brief statement of the conditions on which the

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Indented Steel Bar Co., Ltd., work, with a list of the various services they are prepared to render to their clients, such as supplying preliminary designs for reinforced concrete structures, with estimates of the probable cost, preparation of detailed working drawings, supervision of work, etc.

***The First Cottbus Cement Goods and Machine* Works,** whose agency is at 1 Laleham Road, Catford, S.E., inform us that 45 millions of concrete interlocking roofing tiles have been made on their machines during the last twelve months. The makers attribute the popularity of these machines as much to their simplicity of construction and speed of output as to the superiority of the tiles made thereby, which are stated to be cheaper and lighter than slate, and to make a stormproof and waterproof roofing.

The British Uralite Co. (1908), who exhibited a pavilion made of their fireproof materials, uralite and asbestone, at the Imperial International Exhibition, London, have been awarded a gold medal and diploma.

The Building and Estates Development Co., Ltd., of Bristol, have issued a neat and copiously illustrated booklet, styled "Picturesque Homes," descriptive of buildings of every kind and size, erected according to the company's three methods of construction, cement slabs, solid concrete walls, and solid moulded concrete blocks, particulars and plans of which are given. The attention of Colonial readers is especially called to Calway's system of building cement slab houses, which, being all framed, bundled, and marked, are easily handled, and most suitable where facility of transport is an important consideration. Another feature of these houses is that it is possible to reproduce exactly, at moderate cost, the old half-timbered houses of the Elizabethan or any other period, as the cement slabs may be moulded into any shape.

CORRECTION.

Anerley School.—In describing this building in our November number, we omitted to mention that the steel construction and walls were erected by Smith, Walker & Co., constructional engineers, of 11 Tothill Street, Westminster, S.W.

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